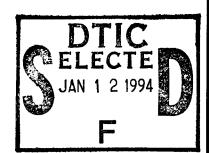




EVALUATION OF A PROPOSED F-4 EJECTION SEAT CUSHION BY +GZ IMPACT TESTS

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

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FOR THE COMMANDER

THOMAS J. MOOKE, Chief

Biodynamics and Biocommunications Division

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During 1986 to 1987, approxin	nately 45 human impact e	experiments were a	accomplished on a vertical			

During 1986 to 1987, approximately 45 human impact experiments were accomplished on a vertical deceleration tower to evaluate the influence of three separate seat cushions on the human biodynamic response during positive vertical (+Gz) impact accelerations that simulated the catapult phase of ejection. The human subjects were exposed to the following three seat cushions at a peak impact level of 10 G: (1) the standard operational F-4 ejection seat cushion, (2) the standard operational ACES II ejection seat cushion, and (3) a proposed F-4 ejection seat cushion composed of ConformTM foam. Principle measurements that were collected and analyzed included seat pan loads, head accelerations, and chest accelerations. Test results showed that the current operational F-4 seat cushion produced greater biodynamic responses (in terms of parameter magnitudes) during vertical acceleration than either the proposed F-4 seat cushion or the ACES II seat cushion.

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PREFACE

The tests described within this report were accomplished by the Escape and Impact Protection Branch, Biodynamics and Biocommunications Division, Crew Systems Directorate of the Armstrong Laboratory. The vertical acceleration (impact) tests were conducted using a vertical deceleration tower to simulate the catapult phase of an aircraft ejection.

The impact facilities, data acquisition instrumentation, and data processing systems were operated by the Scientific Services Division of DynCorp under Air Force Contract F33615-86-C-0531.

Photographic and high-speed film services were provided by the Technical Photographic Division of the 4950th Test Wing.

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INTRODUCTION

The objective of this test program was to measure the influence of specific ejection seat cushions on the human response to vertical acceleration. The test program, requested by the San Antonio Air Logistics Center, compared a proposed seat cushion and the survival kit lid designed to be used to an existing operational seat cushion and survival kit lid. Our study was designed to provide a direct comparison of the human response to vertical acceleration with these two seat cushions. The study also included, as a standard for comparison, a seat cushion that had been used in a previous comparative study (Hearon and Brinkley, 1986).

METHODS

Vertical impact tests were performed using a deceleration tower facility. The test conditions are shown in Table 1. The order of presentation of the test conditions was randomized for each subject. Other test conditions such as the seat geometry, restraint configuration, acceleration time history, and pre-impact position of the subject, were controlled to assure that the measured responses were due only to the differences among the seat cushions and the seat surface on which they were tested.

TABLE 1. EXPERIMENTAL CONDITIONS									
MATRIX CELL DESIGNATION	ACCELERATION (G)	SEAT CUSHION	SEAT SURFACE						
F	10	ACES II	FLAT						
I	10	CURRENT F-4	CONTOURED						
J	10	PROPOSED F-4	FLAT						

Three seat cushions were evaluated. Two of the seat cushions were designed to be used with the F-4 ejection seat. One of the F-4 cushions was a current operational seat cushion manufactured by the Martin-Baker company (part no. MBEU 2866DP). The cushion, shown in Figure 1, consists of two layers of foam. The upper layer (part no. MBEU 2869DP) is a one-inch thick, heavy-density TexfoamTM rubber. The lower layer (part no. MBEU 2870DP) is high-density, PlasazoteTM mold foam one-inch thick on each side. The lower layer is contoured on the top and bottom to fit the seat occupant's buttocks and the buttocks contour molded into the lid of a survival kit. the area of the occupant's ischial tuberosities, the lower layer is 0.5-inch thick. The cushion is used in the U.S. Air Force with a fiberglass survival kit manufactured by Koch and Sons (part no. 140-489-1). The depth of the depression molded in the lid of the kit is 1.50 in. The cushion is covered with a stretchable NomexTM material (Fabratex Corp. part no. 1-771001).

The second cushion (Koch and Sons part no. 159-870286-1), which is also designed for the F-4 ejection seat, is constructed of uncontoured, two-inch thick, type C-47 ConformTM foam (Koch and Sons Part no. 159-870288-1) with a NomexTM cover (Koch and Sons part no. 144-870287-1). This cushion, shown in Figure 2, is designed to be used with a flat survival kit lid manufactured by H. Koch and Son (part no. 024-870280-1). Both the contoured lid and the flat lid are designed to be used with the same survival kit body (Koch and Sons part no. 140-710-1)/

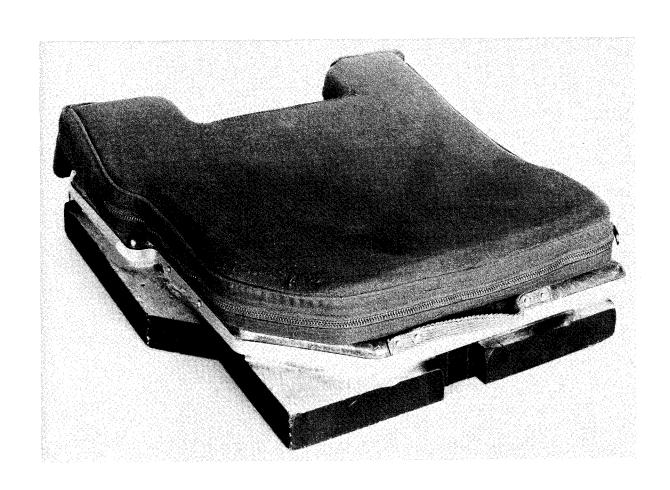


FIGURE 1. OPERATIONAL F-4 EJECTION SEAT CUSHION

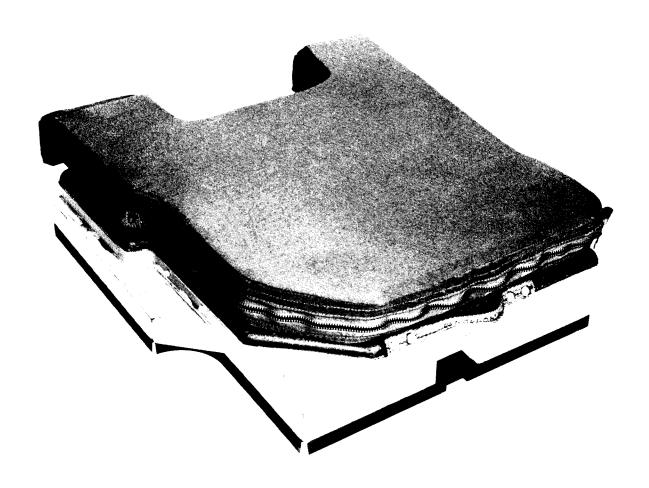


FIGURE 2. PROPOSED F-4 EJECTION SEAT CUSHION

The third cushion that was tested was an ACES II ejection seat cushion (see Figure 3). This cushion consists of three layers of material. The lower layer is 0.39 in (1 cm) thick, sheet foam polyethylene (DMS 1954, Class I, Grade 4101). The middle layer is 0.5 in (1.3 cm) thick type T-47 TemperTM foam. The upper layer consists of 0.25 in (0.6 cm) thick, space fabric (Uniroyal, 6007-1-1-54) to promote air circulation within the cushion. The ACES II cushion is covered with a stretchable NomexTM fabric.

The two F-4 ejection seat cushions were tested on their respective survival kit lids. The contents of the survival kits were assumed to have identical mechanical compression properties, and only differed in the contours of their lids. Each survival kit lid was bonded to a wooden block of identical composition. The kit lid and wooden block were then mounted to a metal plate, which was attached to the structure of the test seat by a force measurement device consisting of six force cells.

The ACES II seat cushion was tested on a flat seat supported by the force cells. The seat was constructed of a wooden block mounted to the metal plate used to attach the six force cells to the seat frame. The surface of the block was covered by a rigid plastic laminate material.

The test seat was the generic design shown in Figure 4. The seat back was positioned at right angles to the uninclined seat pan and parallel to the acceleration vector. The headrest contact plane was one inch (2.5 cm) aft of the seat back. vertical position of the headrest was individually adjusted for each subject in order to provide adequate head support. This vertical headrest position was held constant for each subject during the test program. Seat-back cushions were not used in the study. Also, no footrest structure or leg restraint were provided, so the lower legs were permitted to dangle during the The subjects were restrained by the PCU-15/P torso/ parachute harness and an HBU-type lap belt constructed of 1.72in (4.37 cm) wide, type III polyester webbing (MIL-W-25361C). A MA-1 lap belt buckle was used. Before each test, the restraint system was pretensioned so that the force at the shoulder-strap and lap-belt attachments measured 20 \pm 5 lb (89 ± 22 N). All subject wore the HGU-26/P flight helmet and were initially positioned with head upright, helmet against the headrest, and arms resting on anterior thighs.

The experimental set up and pre-test position of the subject are shown in Figure 5. The test fixture, restraint system, and subject were instrumented to obtain pertinent data during each test. Measured parameters included the translational acceleration of the deceleration tower carriage



FIGURE 3. ACES II EJECTION SEAT CUSHION

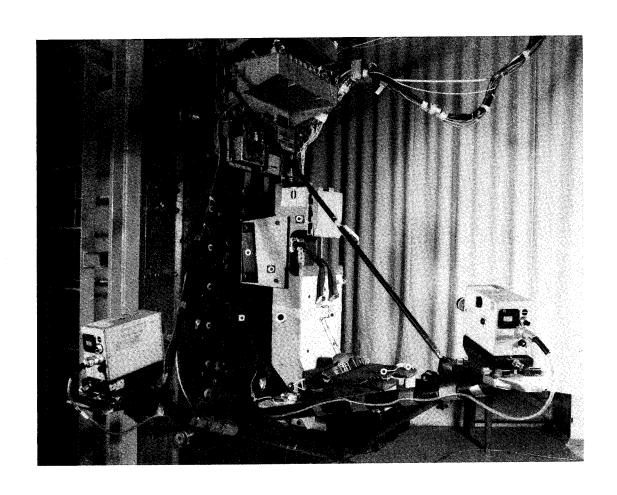


FIGURE 4. TEST FIXTURE



FIGURE 5. PRE-TEST POSITION OF THE TEST SUBJECT

and test seat, angular acceleration of the seat about the Y axis, velocity of the carriage, vertical and horizontal seat forces, and triaxial forces measured at the restraint harness attachment points. Triaxial translational accelerations and angular accelerations about the Y axis were measured at the head and chest of the subject. Photogrammetric data were obtained by two high-speed motion picture cameras mounted on the test fixture, permitting measurement of body displacements. The electronic and photogrammetric data acquisition system is described in detail in Appendix A.

The left-handed coordinate reference system for acceleration (+x anterior, +z cephadalad) was used during data analysis. Electronic and photogrammetric data were processed by a Digital Equipment Corporation PDP-11/34 computer.

The test results were evaluated using the Wilcoxon paired-replicate rank test (Wilcoxon and Wilcox, 1964). This statistical technique was selected to compare the peak values of measured parameters and to establish the statistical significance of observed trends in the data. This analytical approach established each subject as his own control, thereby reducing the effects of biological variability among subjects. The 95th percent confidence level, assuming a two-tailed test, was chosen as the level of statistical significance.

The hypothesis that was statistically evaluated was that there are no differences between the measured human responses regardless of the cushion that is used. Evaluation criteria were based on the fundamental principles of biomechanical Clinically consequential impact injury generally protection. results from differential acceleration of body segments and/or excessive structural loading. For short-duration acceleration applied parallel to the spinal column, human tolerance is apparently limited by vertebral compression fracture. If the risk of such injury is to be reduced, vertebral column loading must be minimized during vertical acceleration. Minimizing head and chest acceleration would also be wise since they may be indicative of potentially injurious internal forces. Accordingly, the key response parameters in this study were the resultant seat force, which is generally reflective of vertebral column loading, and the resultant head and chest accelerations.

The volunteer subjects, 13 men, were active-duty officers and enlisted personnel at Wright-Patterson Air Force Base who were medically qualified for impact acceleration stress experiments. The subjects were required to meet stature, weight, and sitting height criteria for USAF pilots and a complete medical screening more stringent than the USAF flying class II evaluation. Conservative selection criteria were established to yield a subject sample comparable to the USAF

flying population in terms of age and anthropometry, but super normal in terms of susceptibility to impact injury. The characteristics of the subject sample used in this study (in terms of mean and standard deviation) may be summarized as follows: age, 28.8 ± 4.13 years; weight, 174 ± 21.2 lb; height, 70.2 ± 2.70 in; and sitting height, 33.5 ± 1.31 in. These values compare favorably with the means and standard deviations for the USAF flying population (NASA Ref. Pub. 1024). The sizes and weights of the subjects are described and compared to the USAF flying population in Table 2.

	TABLE 2. ANTHROPOMETRY OF TEST SUBJECTS									
SUBJ NO.	WT (LB)	STATURE (IN)	SITTING HEIGHT (IN)	MID-SHOULDER SIT HEIGHT (IN)	BUTTOCK TO KNEE (IN)	AGE (YR)				
B-1	160	70.5	37.1	25.7	23.9	28				
D-5	175	72.0	36.1	25.0	25.0	25				
L-3	190	72.0	37.4	26.1	25.1	36				
L-5	186	69.8	35.6	25.4	25.1	27				
M-16	199	70.0	37.3	25.7	24.6	32				
M-19	181	74.2	38.5	26.1	25.6	26				
M-20	199	70.8	37.0	26.0	25.0	29				
M-21	126	66.0	34.1	23.5	23.0	28				
0-2	178	65.7	34.0	24.0	23.6	26				
P-5	186	68.5	36.0	24.6	23.2	25				
R-8	169	74.6	37.6	26.3	26.4	28				
S-3	167	69.5	36.5	25.5	23.7	38				
Z-2	143	68.3	36.9	25.4	22.9	26				
TEST	SUBJE	T MEANS	AND STANDAR	D DEVIATIONS						
MEAN	173.8	70.2	33.5	25.3	24.4	28.8				
s.D.	21.2	2.7	1.31	0.85	1.09	4.13				
USAF	FLYING	PERSON	NEL (1967 8U)	RVEY)	*					
MEAN	173.6	69.8	36.7	25.4	23.8	30.0				
s.D.	21.4	2.4	1.3	1.10	1.10	6.31				

The tests were conducted using presumed subinjury, short-duration acceleration conditions to minimize the potential for

injury to the subjects. Following a low-level test to familiarize the participants with the test procedures and equipment, a randomized series of tests at a nominal 10 G peak and velocity change of 27 ft/sec (8 m/sec) were initiated. The acceleration profile was an approximate half-sine waveform, and the average time to peak carriage acceleration (rise time) was 70 msec.

The tests were carried out at the Armstrong Laboratory using the Vertical Deceleration Tower (VDT). The test assembly, including seat, restraint, and instrumentation, was mounted to the impact carriage of the VDT. This carriage was raised to a drop height of 10 ft 4 in (3.14 m) and then allowed to fall freely along vertical rails onto a hydraulic decelerator at the base of the tower. The vertical acceleration was produced when a plunger fixed to the bottom of the carriage displaced water in the hydraulic decelerator. To assure identical acceleration conditions, the carriage drop height, test assembly mass, water volume, and plunger type were the same for all experimental-level tests in this study.

RESULTS

The test results are summarized in Table 3 in terms of the means and standard deviations of the measurements for each of the three cushions that were evaluated. Appendix B provides typical sets of electronic data from tests of each cushion and he maxima and minima of each measurement from each test.

TABLE 3. SUMMARY OF DATA									
RESPONSE PARAMETER	CELL F ACES II	CELL I CURRENT F-4	CELL J PROPOSED F-4						
	n = 13	n = 13	n = 13						
SEAT ACCELERATION (G)	10.64 ± 0.38	10.82 <u>+</u> 0.22	10.80 ± 0.29						
RESULTANT SEAT FORCE (LB)	2698 <u>+</u> 362	2775 <u>+</u> 349	2639 <u>+</u> 342						
SEAT FORCE RISE TIME (SEC)	0.079 <u>+</u> 0.007	0.083 ± 0.004							
RESULTANT CHEST ACCELERATION (G)	16.32 ± 2.15	17.53 <u>+</u> 1.98	16.17 ± 1.36						
CHEST ACCELERATION RISE TIME (SEC)	0.079 <u>+</u> 0.005	0.083 <u>+</u> 0.006	0.078 <u>+</u> 0.003						
RESULTANT HEAD ACCELERATION (G)	13.76 <u>+</u> 1.29	15.38 ± 1.17	13.42 ± 0.95						
HEAD ACCELERATION RISE TIME (SEC)	0.077 ± 0.005	0.080 <u>+</u> 0.004	0.078 <u>+</u> 0.003						
RESULTANT SHOULDER-STRAP FORCE (LB)	191 <u>+</u> 72.5	178 <u>+</u> 58.3	188 <u>+</u> 52.7						
LEFT LAP-BELT FORCE (LB)	110 <u>+</u> 35.0	99 <u>+</u> 33.6	103 <u>+</u> 19.7						
RIGHT LAP-BELT FORCE (LB)	104 <u>+</u> 25.0	91 <u>+</u> 31.4	97 ± 23.7						

The results of each set of Wilcoxon comparisons are summarized in Table 4.

TABI	E 4. WILCOXON COM	IPARISON SUMMARY	
RESPONSE PARAMETER	CURRENT F-4 (I) PROPOSED F-4 (J)	1	CURRENT F-4 (I) ACES II (F)
	n = 13	n = 13	n = 13
RESULTANT SEAT FORCE (LB)	I > J 99%	F = J	I > F 99%
RESULTANT CHEST ACCELERATION (G)	I > J 98%	F = J	I > F 99%
RESULTANT HEAD ACCELERATION (G)	I > J 99%	F = J	I > F 99%
Percentages designa	te statistical cor	nfidence level	

For a given comparison, a greater-than or less-than symbol designates a statistically significant difference in the response parameter at the chosen 95 percent confidence level; the symbol also indicates the direction of the trend, i.e., whether it increases or decreases in value from one cell to the other.

The seat acceleration for all 39 experimental-level tests in this study was well controlled during the evaluation. The maximum seat accelerations for each replicate set of tests were statistically evaluated for differences using the Wilcoxon analysis. Statistically significant differences were not found.

Direct comparisons of the two F-4 cushions are shown in the first comparison listed in Table 4. The evaluation parameters of seat force, head acceleration, and chest acceleration were all lower when the proposed F-4 cushion was used. The comparison of the proposed F-4 cushion with the ACES II cushion, shown in the second column of matched pairs, revealed no statistically significant differences. Comparison of the operational F-4 cushion with the ACES II, shown in the third column of matched pairs, revealed statistically significant differences in all of the evaluation parameters with lower values being measured with the ACES II cushion.

Each of the test conditions were well tolerated by the volunteer subjects. There were no injuries resulting from any of the tests.

DISCUSSION

The current operational seat cushion was selected for USAF use as a result of a series of ejection tests by Brinkley et al (August 1967) using a Martin Baker ejection seat with reducedcharge catapults. Three cushion conditions were evaluated: the Martin Baker cushion, a cushion developed by the McDonnell-Douglas Corporation, and no seat cushion. Forty-nine tests were conducted with seven human subjects at acceleration levels ranging from 6 to 14 G. The principal measurement that was used to evaluate the relative merits of the three cushion conditions was the vertical force between the accelerating seat and a simulated survival kit lid upon which a volunteer subject was seated. Typical data acquired from the ejection tests are plotted in Figure 6. Figure 6 is a plot of the ejection force (the measured seat acceleration times the subject mass) versus the vertical force measured between the seat and the survival kit lid. The seat acceleration level for this test was 9.9 G.

Although these tests more closely simulated actual F-4 ejection seat accelerations and seat geometries, the tests were more costly in time, funding, and injuries. Three of the seven subjects who participated in the tests incurred cervical, thoracic, and lumbar-sacral paravertebral sprains. One subject incurred a fracture of the spinal coccyx.

Analysis of the data collected during the earlier series of tests showed that seat force, the measured response used to comparatively evaluate the cushions, reached its critical value within about 0.10 sec to 0.12 sec.

This relationship can be clearly seen in Figure 6. Thus, one can conclude with confidence that only the first 0.1 sec of the catapult acceleration was crucial to the cushion evaluation. Furthermore, although the earlier tests were accomplished at acceleration levels from 6 to 14 G, the beneficial effects of the Martin Baker seat cushion could be seen at a level of 8.7 G. These results have led us to conclude that simpler tests at acceleration levels that represent a lower risk of injury to the volunteers will provide equivalent results.

Although the influence of the acceleration-transmission characteristics of an ejection seat is crucial, other factors should also be seriously considered. These factors include durability, flammability toxicity of gases produced during combustion, long-duration crew comfort, changes of mechanical properties as a function of temperature and age, and changes in the seat occupant's position that might influence the effectiveness of the cockpit layout or escape system

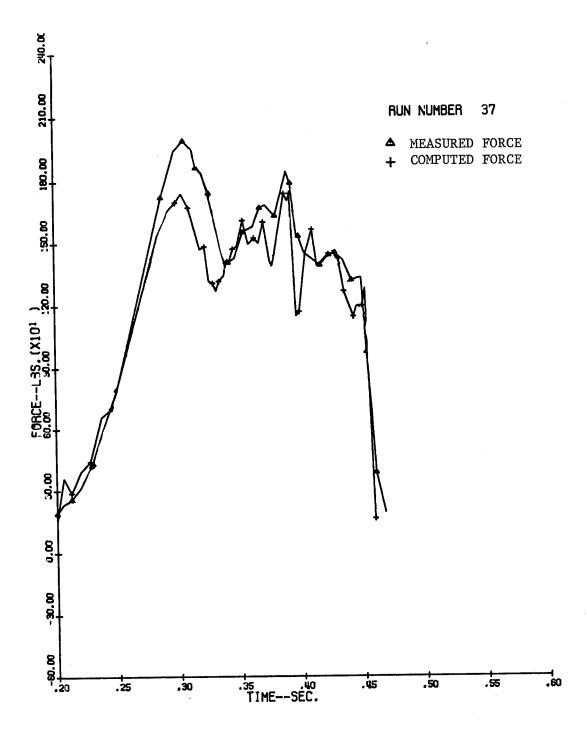


FIGURE 6. PLOT OF MEASURED FORCE AND COMPUTED FORCE FROM F-4 EJECTION SEAT TEST WITH HUMAN SUBJECT

performance. If any or all of these factors represent critical issues to the operational application, they should be thoroughly evaluated.

The long-duration comfort of the ConforTM foam has been demonstrated by tests in the F/FB-111 aircraft, and more recently by long-duration flights of the B-1B bomber. The thickness of the F/FB-111 cushions and B-1B cushions that were tested is identical to the proposed F-4 cushion that was tested by our Laboratory. Both the F/FB-111 and B-1B crew seats are contoured, although the contours are different. The B-1B seat cushion has been tested with the production contoured seat and with a flat seat. No significant difference was noticed by the crew; therefore, a decision was made by the B-1 System Program Office to use the cushion with the existing contoured seat.

CONCLUSION

The results of these tests show that the human response to vertical acceleration was more benign when either the proposed F-4 seat cushion or the ACES II seat cushion was used instead of the current operational F-4 seat cushion. From an acceleration protection standpoint, the operational F-4 cushion is inferior to the proposed alternative cushion or the operational ACES II cushion.

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TEST CONFIGURATION AND DATA ACQUISITION SYSTEM FOR THE EFFECTS OF SEAT CUSHIONS AND SEAT BACK ANGLE ON HUMAN RESPONSE DURING +GZ IMPACT ACCELERATION TEST PROGRAM

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Prepared by

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INTRODUCTION

This report was prepared by DynCorp (formerly Dynalectron Corporation) for the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL/BBP) under Air Force Contract F33615-86-C-0531.

The information provided herein describes the test facility, test fixture, data acquisition, instrumentation procedures and and the test configuration that were used in "The Effects of Seat Cushions and Seat Back Angle on Human Response During +Gz Impact Acceleration Test Program." The testing was done on the Vertical Deceleration Tower starting July 1986 and ending August 1986.

1. TEST FACILITY

The AAMRL Vertical Deceleration Tower, as shown in Figure A-1, was used for all of the tests.

The facility consists of a 60 ft. vertical steel tower which supports a guide rail system, an impact carriage supporting a plunger, a hydraulic deceleration device and a test control and safety system. The impact carriage can be raised to a maximum height of 42 ft. prior to release. After release, the carriage free falls until the plunger, attached to the undercarriage, enters a water filled cylinder mounted at the base of the tower. The deceleration profile produced as the plunger displaces the water in the cylinder is determined by the free fall distance, the carriage and test specimen mass, the shape of the plunger and the size of the cylinder orifice. For these tests, plunger number 102 was mounted under the carriage. Drop height varied depending on the test cell requirements which ranged from 5'6" to 8'3".

2. SEAT FIXTURE

The VIP seat fixture, as shown in Figure A-1, was used for all of the tests. The seat was designed to withstand vertical impact acceleration up to 50 Gs. Its adjustable seat back allowed the subject to sit in one of four positions, as shown in Figure A-2. When positioned in the seat, the subject's upper legs were bent 90 degrees outward to a horizontal position with his lower legs bent 90 degrees downward to a vertical position. The subject was secured in the seat with a lap belt and shoulder strap. The lap belt and shoulder strap were preloaded to 20+ lbs. as required in the test plan.

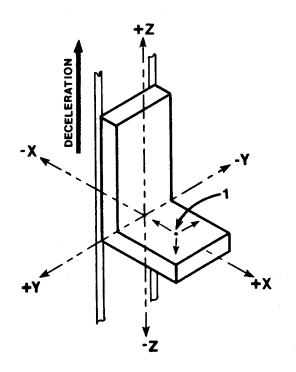
INSTRUMENTATION

The electronic data collected during this test program is described in Sections 3.1 and 3.2. Section 3.1 discusses accelerometers while Section 3.2 discusses load transducers. Section 3.3 discusses the calibration

procedures that were used. The measurement instrumentation used in this test program is listed in Tables A-la through A-lc. These tables designate the manufacturer, type, serial number, sensitivity and other pertinent data on each transducer used.

Accelerometers and load transducers were chosen to provide the optimum resolution over the expected test load range. Full scale data ranges were chosen to provide the expected full scale range plus 50% to assure the capture of peak signals. All transducer bridges were balanced for zero output except for those accelerometers in line with the force of gravity which were adjusted for plus 1 G. The accelerometer and load transducer coordinate system is shown in Figure A-3.

The accelerometers were wired to provide a positive output voltage when accelerations were applied in the +x, +y and +z directions, as shown in Figure A-3.



1. Typical fixed load cell and load link mounting point. Direction of arrows indicate direction of force applied to produce a positive output.

NOTE: Accelerometers were wired to produce a positive output voltage when accelerations were applied in the +x, +y and +z directions as shown.

FIGURE A-3: AAMRL/BBP COORDINATE SYSTEM

The load transducers included three types of load measurement devices. All were wired as follows:

<u>Fixed Load Cells</u> - were wired to provide a positive output when force is applied in the indicated direction (Figure A-3).

Triaxial Load Cells - were wired to provide a positive output when the belt was pulled towards the center of the seat.

<u>Load Links</u> - were wired to provide a positive output when force is applied in the direction indicated (Figure A-3).

Carriage velocity was measured using a Globe Industries tachometer Model 22A672-2. The rotor of the tachometer was attached to an aluminum wheel with a rubber "O" ring around its circumference to assure good rail contact. The wheel contacted the track rail and rotated as the carriage moved, producing an output voltage proportional to the velocity.

3.1 Accelerometers

This section describes the accelerometer instrumentation as required in the AAMRL/BBP test plan.

Head accelerations were measured using three Endevco Model 2264-200 linear accelerometers and one Endevco Model 7302A angular (Ry) accelerometer. The accelerometers were mounted to the external edge of a plastic dental bite block. Each subject had his own set of custom fitted dental inserts that were used to support the bite block in his mouth. An aluminum tube extended from the bite block and located a fiducial target used for photo tracking purposes.

The chest accelerometer package consisted of three Endevco Model 2264-150 linear accelerometers mounted to a $1/2 \times 1/2 \times 1/2$ inch aluminum block. An Endevco Model 7302A angular (Ry) accelerometer was mounted on a bracket adjacent to the triaxial chest block. The accelerometer packages were inserted into a steel protection shield to which a length of Velcro fastener strap was attached. The package was placed over the subject's sternum at the level of the xiphoid and was held there by fastening the Velcro strap around the subject's chest.

Carriage accelerations were measured using three Endevco accelerometers: Model 2262A-200 for the z direction, Model 2264-200 for the x direction and Model 7264-200 for the y direction. The three accelerometers were mounted on a small acrylic block and located behind the seat on the VIP seat structure.

Seat accelerations were measured using three Endevco accelerometers: one Model 2264-150 for accelerations in the x direction and two Model 2264-200s for accelerations in the y and z directions. Seat angular (Ry) acceleration was measured using an Endevco Model 7302B angular accelerometer. The three linear accelerometers were attached to a 1 x 1 x 3/4 inch acrylic block and were mounted below the seat near the back

edge of the support frame. The angular accelerometer was attached to an aluminum bracket and was mounted near the center and below the seat.

Head accelerations for dummy tests were measured using three Endevco Model 2264-200 linear accelerometers and one Endevco Model 7302 angular accelerometer. These accelerometers were internally mounted in the head of the VIP 95 manikin.

3.2 Load transducers

This section describes the load transducer instrumentation as required in the AAMRL/BBP test plan.

The load transducer locations and dimensions are shown in Figure A-4.

Right lap, left lap and shoulder strap loads were each measured using GM3D-SW triaxial load cells, each capable of measuring loads in the x, y and z directions. The shoulder strap triaxial package was mounted on the seat frame between the seat back support plate and the headrest. The right and left lap triaxial packages were located on separate plates mounted on the side of the seat frame parallel to the seat pan.

Seat pan loads were measured using three load cells and three load links. The three load cells were Strainsert Model FL2.5U-2SPKT load cells. The three load links, as shown in Figure A-5, were fabricated by DynCorp using Micro Measurement Model EA-06-062TJ-350 strain gages. All six measurement devices were located under the seat pan support plate. The load links were used for measuring loads in the x and y directions, two in the x direction and one in the y direction. Each load link housed a swivel ball which acted as a coupler between the seat pan and load cell mounting plate. The Strainsert load cells were used for measuring loads in the z direction.

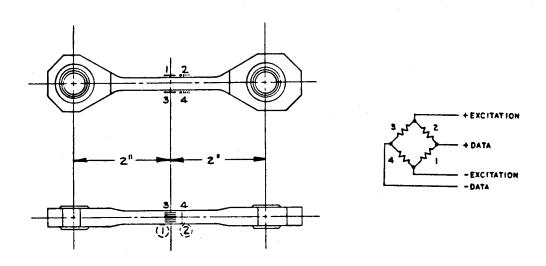


FIGURE A-5: LOAD LINK INSTRUMENTATION

3.3 Calibration

Calibrations were performed before and after testing to confirm the accuracy and functional characteristics of the transducers. Pre-program and post-program calibrations are given in Tables A-2a through A-2d.

The calibration of all Strainsert load cells was performed by the Precision Measurement Equipment Laboratories (PMEL) at Wright-Patterson Air Force Base. PMEL calibrated these devices on a periodic basis and provided current sensitivity and linearity data.

The calibration of the accelerometers was performed by DynCorp using the comparison method (Ensor, 1970). A laboratory standard accelerometer, calibrated on a yearly basis by Endevco with standards traceable to the National Bureau of Standards, and a test accelerometer were mounted on a shaker table. The frequency response and phase shift of the test accelerometer was determined by driving the shaker table with a random noise generator and analyzing the outputs of the accelerometers with a PDP 11/15 computer and 1923 Time Data Unit using Fourier analysis. The natural frequency and the damping factor of the test accelerometer were determined, recorded and compared to previous calibration data for that test accelerometer. Calibrations were made at 40 G and 100 Hertz. The sensitivity of the test accelerometer was determined by comparing its output to the output of the standard accelerometer.

The angular accelerometers were calibrated by DynCorp by comparing their output to the output of a linear standard accelerometer. The angular accelerometer is mounted parallel to the axis of rotation of a Honeywell low inertia D.C. motor. The standard accelerometer is mounted perpendicular to the axis of rotation at a radius of one inch to measure the tangential acceleration. The D.C. motor motion is driven at a constant sinusoidal angular acceleration of 100 Hertz and the sensitivity is calculated by comparing the rms output voltages of the angular and linear accelerometers.

The velocity wheel was calibrated by rotating the wheel at various revolutions per minute (RPM) and recording both the output voltage and the RPM. The sensitivity was dynamically checked with a G-HI measuring system and the Horizontal Accelerator Sled facility. This system consists of a timing unit and an optical sensor mounted near the track rails. As the sled traveled along the track rails, a metal blade on the sled interrupted the optical sensor beam. The timing unit displayed a time which was correlated to a velocity.

The load links and GM load cells were calibrated by DynCorp. These transducers were calibrated to a laboratory standard load cell in a special test fixture. The sensitivity and linearity of each test load cell were obtained by comparing the output of the test load cell to the output of the laboratory standard under identical loading conditions. The laboratory standard load cell, in turn, is calibrated by PMEL on a periodic basis.

4. DATA ACQUISITION

Data acquisition was controlled by a comparator on the Master Instrumentation Control Unit in the Instrumentation Station. The comparator was set to start data collection at a preselected time. A reference mark was electronically initiated to mark the electronic data and initiate a stobe light in the test area to mark the film frame for reference. The test was initiated when the countdown clock reached zero. The reference mark, used in the processing of data, was generated after $T = \emptyset$ to place the reference mark close to the impact point.

Timing reference was provided by a master clock. Timing pulses of 100 pps were provided by the master clock to film data. The cameras were run at 500 frames per second and a timing pulse was placed on the film at 10 millisecond intervals.

Prior to each test and prior to placing the subject in the seat, data was acquired to establish a zero reference for all data sensors. This data was stored separately from the test data and was used in the processing of data.

4.1 Automatic Data Acquisition and Control System (ADACS) Installation of the ADACS instrumentation is shown in Figure A-6. The three major components of the ADACS system are the power conditioner, signal conditioners and the encoder. A block diagram of the ADACS is shown in Figure A-7. The signal conditioners contain forty-eight module amplifiers with programmable amplifier gains and filters.

Bridge excitation for load cells and accelerometers was 10 VDC. Bridge completion and balance resistors were added as required to each module input connector.

The forty-eight module output data signals were digitized and encoded into forty-eight 11-bit digital words. Two additional 11-bit synchronization (sync) words were added to the data frame making a fifty word capability.

Three synchronization pulse trains (bit sync, word sync and frame sync) were added to the word frame and sent to the computer via a junction box data cable.

The PDP 11/34 mini-computer received serial data from the ADACS. The serial data coming from the carriage were converted to parallel data in the data formatter. The data formatter inputs data by direct memory access (DMA) into the computer memory via a buffered data channel where data were temporarily stored on disk and later transferred to magnetic tape for permanent storage. The interrelationships among the data acquisition and storage equipment are shown in Figure A-8.

Test data could be reviewed immediately after each test by using the "quick look" SCAN routine. SCAN was used to produce a plot of the data

stored on any channel as a function of time. The routine determined the minimum and maximum values of any data plot. It was also used to calculate the rise time, pulse duration and carriage acceleration.

4.2 Photogrammetric Data Acquisition
Two onboard high-speed LOCAM cameras, operating at 500 frames per second, were used to produce the photogrammetric data. Each camera used a 9mm lens and were automatically started at a preset time in the test sequence by a signal from the camera and lighting control station. Both camera locations are shown in Figure A-9.

Motion of the subjects' head, shoulders and chest were quantified by tracking the motion of subject-mounted fiducials. Reference fiducials were placed on the test fixture. Two different sized fiducials were used, one being a .75" diameter black circle on a 1.25" diameter white target, the other a 1.25" diameter black circle on a 2.00" diameter white target. The locations of the fiducials generally followed the guidelines provided in "Film Analysis Guides for Dynamic Studies of Test Subjects, Recommended Practice" (SAE J138, March 1980). Fiducial target locations are identified in Figure A-10.

The photogrammetric data were time correlated in each test. Immediately prior to impact, an event signal triggered the flash unit to mark the camera film frame. At that time, a 100 PPS signal activated the camera L.E.D. driver which pulsed the camera L.E.D., producing a time mark at the film edge. This reference mark was then used to correlate the photogrammetric data with the electronically measured data.

The photogrammetric data will be processed as required on the Automatic Film Reader (AFR) system, shown in the block diagram in Figure A-11. The fiducial tracking routine is initiated via the Data General terminal. The tracking routine is booted from a floppy disk into the Nova 3/12 memory. The system is capable of tracking fiducials manually or automatically. The Nova 3/12 outputs an x-y film coordinate position to magnetic tape for each fiducial being tracked. Data are then transferred from magnetic tape to the DEC PCP 11/34 disk file for processing.

An Instant Analytical Replay (INSTAR) video system was also used to provide photogrammetric coverage of each test. This video recorder and display unit is capable of recording high-speed motion at a rate of 120 frames per second. Immediate replay of the impact is possible in real time or in slow motion.

5. PROGRAM OPERATION

5.1 Introduction

This section identifies the flowcharts and processing programs that were used for the VSBA Study conducted by the Biomechanical Protection Branch, Biodynamics and Bioengineering Division of the Harry G. Armstrong Aerospace Medical Research Laboratory.

The executable tasks for the VSBA Study processing programs are located on the Data Processing disk of the PDP 11/34. The test data is read into the computer using the DEC Peripheral Interchange Package from a digital magnetic tape with a density of 800 BPI and stored on an RLØ2 hard disk. All plots are output to a Tektronix hardcopy unit. The alphanumeric data itself is output to the Versatec line printer.

5.2 Program Operation

The five Fortran programs that process the VSBA Study test data are named "VSVDØA," "VSVDØB," "VSVDØC," "VSVDØD" and "VSVDØE." The command file which controls execution of these tasks is named "VSVD." The two characters "VS" identify the study (VSBA), the characters "VD" identify the facility (Vertical Deceleration Tower), "Ø" is the revision number and the last character determines the program order of execution.

Task A requires the user to enter the total number of tests to be processed and the zero and data filenames for each test. The user must then specify whether the default test parameters are to be used for processing. If the default parameters are selected, then the test number, subject identification, weight, age, height and sitting height are read in from the first block of the test data file. The cell type, nominal G level and left lap, right lap and shoulder preload values are also read in. If the default parameters are not selected, they must be entered by the user. Task A creates a command file containing execution commands for each test, which is called by command file "VSVD" after task A exits.

Task B creates the individual data files for each channel and data files for all sums, differences, products and resultants. Task C finds data maxima and minima for each channel, does any special processing required and outputs results to the data base. Task D outputs an alphanumeric cover sheet to the Versatec line printer/plotter based on the formats specified in the base and report format files. Task E plots the specified data channels for 600 ms after the reference mark and hardcopies the plots.

5.3 Program Flowcharts

Flowcharts of the five programs are shown in Figures A-12 through A-16. Each flowchart identifies the files used and the subroutines called by the program. Data channel numbers and accelerations or loads are listed where they occur in the analysis.

PEOGRAM	THE EPP N SEAT CU	THE EFFECTS OPIGITAL INSTINUMENTATION SEAT CUSHION AND SEAT BACK ANGLES DURING YOU	ITAL IN	STRUMEN ANGLES DUE		RECUMENENTS		THEU 14 AIC 54	48 2H		IANX	BCT	Non	NAME OF THE PROPERTY OF THE PR
FACILITY	FACHITY VERTICAL DECELLE	PECTURE.	ATOR TOWER		- 1			THE U_1214		ļ			3	
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	BATA POINT	EBUCER WPO & TYPE	₹,0	EBUCEA	incm.	SALTER BRIES BANG	**************************************	ivane.	1	PILTER	200	BALANCE NESSTORE	SELECTE COMMUNICATION RESISTORS	SPECIAL MOTATIONS
-	Carriage	Endevco 2262A- 200	1142	4.20	10.00	03	200	1	23.8 6	120	2.5	100K •in Gnd	-	
~	Carriage X	2 %	BX17	2.792	10.00	3 /	001	IK 1	8.95 g	120	2.5	143K tin God	1.58K	
-	Corriage	Endevco 7264-200	M7 644	2.767	10.00	3/	11 001	=	9.04 8	120	2.5	270K +in Gad		
•	Head X	Endevco 2264-200	9548	2.821 mv/6	10.00	3	, ,	K	17.7 8	120	2.5	-	1.65K	
•	Head Y		6243	2.224 mv/g	10.00	\$ 09	2 00	IK 1	22.4 6	120	2.5	130K +in Gad	-	
•	Head 2		CH73	2.741 mv/g	10.00	9 09	, ,	IK 1	36.5 g	120	2.5	165K •śn Gng	r	
•	Cheet X	Endevco 2264-150	9 23 €	2.807	10.00	, os	\$1	1	17.6 g	120	2.5	1.2N -in God	3	
•	Chase Y	:	£1 94	2.467	10.00	09	001	1	10.1	120	2.5	220K		
•	Cheet 2	1	02¥2	2.648	00:01	09	" "	K	37.8 &	120	2.5	185K -in God	ŧ	
2	2 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	Strainser FL2.5U- 2SPKT	3294-1	8.02 uv/1b	10.00	07	201	1	1381 178	120	2.5	•	•	
Ξ	Right Seat Load		3294-2	8.03 uv/16	10.00	000	201	X 1	1549 LB	120	2.5	,		
11	Center Seat Load		3-9626	8.08 uv/1b	10.00	21 09	78 78	IK .	3094 LB	129	2.5	-	•	
n	Left Load Link X	мм/рти EA-06-062 TJ-350	2	10.32 uv/1b	10.00	60	1 200	IK 1	603 LB	120	2.5	140K •ia Gad	•	
=	Right Load Link X	ż	r	10.55 uv/1b	10.00	91 09	, , , ,	IK I	97 685	120		24K +in Gnd	-	
NO FAC COMPUTE PER HR.	NO FACILITY INFACT SWITC COMBUTER SOFTWARE WILL DE FER HR. BRINKLEY 14 JULY .	HO PACILITY INPACT SHITCH REQUIRED. COMPUTER SOFTNARE WILL DETERMINE THIS POINT PER NR. MRINKLEY 14 JULY 66.	REQUIRED. RHINE THIS	F019T										
														PA61 104

TABLE A-1a: INSTRUMENTATION REQUIREMENTS (PAGE 1 OF 3)

PROORA	THE RPPECTS OF OPER PROPERTY OF THE PROPERTY O	THE EFFECTS OF GITAL SEAT CUSHION AND SEAT I	- 3	ITAL INSTRUMENTATION SEAT BACK ANGLES DURING +GR.	_ 1	DATE 14 JUL 86		THRU 14 AUG 86	AUG B6	C	IVN	EC.	<u> </u>	NORTH A ROARD NORTH ANALY
FACHITY	FACHITY VERTICAL DECELERAL	L DECELERA	FOR TOWER			RUM 1127		148U 1214	4	1				To come come to come
DATA CHARMEL	PATA	ROUCES MFG & TYPE	\$	MONCEN 8618	Encine Susas	WILTER MARY				AT THE	100000	BALANCE MASSTORE	COMPLETION NESSTONS	SPECIAL NOTATIONS
2	Lep Ved X	36-5K	15%	5.36 uv/1b	10.00	21	103	<u>=</u>	1160 1.8	120	2.5 5.0 0.0 0.0	5.2K	,	
91	Left Lap Load 7		157	5.35 uv/1b	10.00	3/31	2 200	1	3 45	120	" "	16K +in Cnd	•	
2	2 2 2 2 2 2 2		132	6.29 uv/1b	10.00	3 (2	*02 2	<u> </u>	11 686	120	2,5	4.9K +in Gnd		
9.	Right Lap Load X		21X	5.07 uv/1b	10.00	3	⁶⁰²	<u>-</u> -	1227 1.8	120	 	8.2K	,	Test 1127-1210 Sems. 0 4.89 uv/1b, F. S. 0 1272 LB
£	Right Lap Load Y	2	211	4.85 uv/1b	10.00	3	800	1 1	11 449	120	2. 2.000 0.0000 0.000 00	3.7K +in Cad	•	Test 1127-1210 Sems. @ 4.82 ww/lb, F. S. 648 LB
20	Right Lep Load 2		212	6.08 ev/1b	10.00	02 03	402	1 1	1023 1.8	120	7.5.0	47K +in God		Test 1127-1210 Sens. @ 6.15 uv/1b, F. S. 1011 LB
12	Shoulder Load X		202	6.29 uv/1b	10.00	17 09	,007	1	11 666	. 021	۲ ا ا ا ا ا	48K -in Gad	1	
ıı	Shoulder Load Y		201	5.78 uv/1b	10.00	27 09	000	1 1	87 TB	120	2.5	BOOK +in Ond	ı	
23	Shoulder Load 2		20K	5.57 vv/lb	10.00	60 23	402	11	an 4111	120	2.5	30K +in Gad		
25	Seat X Accel.	Endevco 2264-150	1828	2.700 mv/g	10.00	60	50 5	11	18.5 g	120	2.5 0.8 0.0	72.4K +in Gnd	1.65K	
36	Seat Y Accel.	Endevco 2264-200	BV95	2.985 mv/g	10.00	97 09	51 05	11	16.8 g	120	2.5 2.5.0 2.0.0 2.0.0 3.0 3	1	1.678	
23	Seet Z Accel.	2	1000	2.812 mv/g	10.00	12 09	20 24	1 1	17.8 €	120	200	287K -in God		
28	Center Load Link Y	MM/DYN EA-06-06 2TJ-350	5	9.91 uv/1b	10.00	97 09	107	11	629 LB	120	2.5 2.6 6.6 6.6	82K +in Cod	,	
53	Vel. Tach.	Globe 22A672- 2	•	.06209 V/F/S	62	1 00		14	80.5	9	0.0 5.0 0.8	-	-	Signal attenuated by 7.65 Sena.=.475 V/F/S + 7.65=.06209 V/F/B 84.4" cir.
11 81	TEST 1145 - SEAT TRIAXIAL LOCATION PER P		PACKAGE H R. BRINKLI	OVED TO BE	PACKACE MOVED TO BEAR OF SEAT PROM CENTER 8. Brinkley.	PROM CENT	5							

TABLE A-1b: INSTRUMENTATION REQUIREMENTS (PAGE 2 OF 3)

		-												
NI N	DATA	REACES RPG &	ŝ	Maucen	I COME	100			**	PH.TER	10mm 1 mm	BALANCE RALANCE	COMPLETION RESETONS	SPECIAL MOTATIONS
'n	Loant	'	,	-	1,	1000	2.2	1 1	5.0 Volt	2000	3.0	ı	•	
2,	Head By Anguler	Endevco 7302A	2164	4.15uv/ mad/sec	10.00	3/3	101	14	2997	120	2.5.0	٠	'	
\$	Chest Ry Anguler		\$167	6.68ev/2	10.00	3/2	102	11	1862 RAD/SEC ²	120	2:5 0:0 0:0	440K -in Cod	,	
3	Seat By Angular	7302B	747	3.63uv/ ₂ RAD/8EC	10.00	3	12	1	1704 RAD/SEC ²	120	2.5 6.5 6.6 6.6	ł	٠.	
2	- 2		1	1		10001)K	5.0 Volt	2000	0.0	•	•	Used for computer processing
ì	2.5 Volt	,	,	'	1/2) . (-	1 1	2.5 Volt	360	2.5.	•		
3	10 Volt Enc.		,	٠	/3	08_ 0	-	11 1	2.5 Volk	960	2.5	•	'	
s	Burny Head X	Endevco 2264-200	₹.8	2.906 av/g	6.00 8	3 8	05	1K 1	17.2 8	021	2.5	190K •in Gad	1.63K	Dummy tests 1131 and subsequent
ž	T P		BQ\$2	2.740	10.00	3/10	20,	15	18.2 8	120	2.5	220K +in Cad	1.69K	Damy tests 1131 and subsequent
2	E S	1	CH70	2.662	10.00	21	200	11	37.6	120	2.5	BOK +in Cad	1.634	Dumy tests 1131 and subsequent
5	No 3d Ang	Endevco 7302	A150	8.163uv MAD/SEC	10.00	3,	100	1	3063 3063 2007 3063	120	2.5	•	•	Dumny tests 1131 and subsequent

TABLE A-1c: INSTRUMENTATION REQUIREMENTS (PAGE 3 OF 3)

THE EFFECTS OF SEAT CUSHION AND PROCRAM: SEAT BACK ANGLES DURING +Gz

DATES: 14 JUL 86 - 14 AUG 86

RUN NUMBERS: 1127-1214 FACILITY: VERTICAL DECELERATION TOWER

			PRE	PRE-CAL	POST	POST-CAL		
DATA POINT	MFG. \$ HODEL	NUMBER	DATE	* SENS	DATE	* SENS	* CHANGE	MOTES
CARRIAGE Z	ENDEVCO 2262A-200	FR42	730186	4.20	20AUG86	4.189	3	* ALL SENS. IN mv/g
CARRIAGE X	ENDEVCO 2264-200	BX17	810186	2.792	=	2.804	+.4	
CARRIAGE Y	ENDEVCO 7264-200	н26на	92016	2.767	ŧ	2.783	9.+	
неар х	ENDEVCO 2264-200	BP56	28MAY86	2.821	14AUG86	2.839	9.+	
неар у	Ε	CF23		2.224	Ŧ	2.257	+.4	
HEAD Z	Ŧ	СН73	ı	2.741	•	2.751	+1.5	
CHEST X	ENDEVCO 2264-150	BC26		2.807	:	2.795	4	
CHEST Y		BB13	E	2.467	ŧ	2.438	-1.2	
CHEST 2	=	2A20		2.648		2.633	9	
SEAT X	2	BB28	31DEC85	2.700	20AUG86	2.701	0	

SEFTERBER 1985

PAGE 1 OF 4

TABLE A-2a: TRANSDUCER PRE- AND POST-CALIBRATION (1 0F 4)

THE EFFECTS OF SEAT CUSHION AND PROGRAM: SEAT BACK ANGLES DURING +Gz

DATES: 14 JUL 86 - 14 AUG. 86

RUN NUMBERS: 1127-1214 FACILITY: VERTICAL DECELERATION TOWER

ALL SENS. IN mv/g UNLESS NOTED OTHER-WISE. HOTES * CHANGE +.5 ÷.5 +1.0 +2.2 +.3 +1.8 +.1 +1.1 0 6.80 uv/RAD /SEC uv/RAD 8.203 uv/RAD /SEC 3.732 uv/RAD /SEC 2.939 2.740 4.195 2.820 2.676 2.987 DATE * SENS POST-CAL uv/RAD 22AUG86 22AUG86 15AUG86 15AUG86 20AUG86 = E = 6.68 uv/RAD /SEC 4.15 uv/RAD /SEC uv/RAD 2.662 28MAY86 2.985 28MAY86 2.906 8.163 9JAN86 2.812 2.740 * SENS 3.65 PRE-CAL 29MAY86 28MAY86 6JAN86 29MAY86 DATE = £ CH74 AB15 BV95 AB12 BW07 A150 PT47 SERIAL BQ42 CH70 TRANSDUCER ENDEVCO 2264-200 ENDEVCO 7302 ENDEVCO 7302A ENDEVCO 7302B ENDEVCO 7302A = = = DUMMY HEAD ANG. CHEST ANG. DATA POINT HEAD ANG. SEAT ANG. DUMMY HEAD Y DUMMY HEAD Z 2 HEAD X SEAT Y DUMMY SEAT

SEPTEMBER 1985

PAGE 2 of

TABLE A-2b: TRANSDUCER PRE- AND POST-CALIBRATION (2 OF 4)

DATES: 14 JUL 86 - 14 AUG 86 THE EFFECTS OF SEAT CUSHION AND PROGRAM: SEAT BACK ANGLES DURING +6z

FACILITY: VERTICAL DECELERATION TOWER

RUN NUMBERSt 1127-1214

			PRE	PRE-CAL	POST	POST-CAL		
note soint	TRAMSDUCER MFG. & HODEL	SER IAL NUMBER	DATE	* SENS	DATE	* SENS	* CHANGE	ន
LEFT LOAD	MM/DYN EA-06-062TJ-	2	9JUL86 10.32	10.32	25AUG86	10.32	0	* NOTE - ALL SENS. IN uv/lb
RIGHT LOAD LINK X		es .	=	10.55	E	10.66	+1.0	
CENTER LOAD	=	5	=	16.6	=	9.94	+.3	
LEFT LAP	GM 3D-SW	15%	ŧ	5.36	ŧ	5.41	6.4	
LEFT LAP LOAD Y	Ξ	151	:	5.35	5	5.36	+.2	
LEFT LAP	E	152	ε	6.29	1	6.30	+.2	
RIGHT LAP LOAD X	=	21X	2	5.07	ŧ	5.08	+.2	
RIGHT LAP LOAD Y	=	217	£	4.85	ŧ	4.84	2	
RIGHT LAP LOAD Z	r	212	2	90-9	:	6.07	2	
SHOULDER LOAD X	±	202	ε	6.29	26AUG86	6.32	+.5	

SENTENBER 1985

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TABLE A-2c: TRANSDUCER PRE- AND POST-CALIBRATION (3 OF 4)

PROGRAM CALIBRATION LOG

PROGRAM: SEAT BACK ANGLES DURING +Gz DI

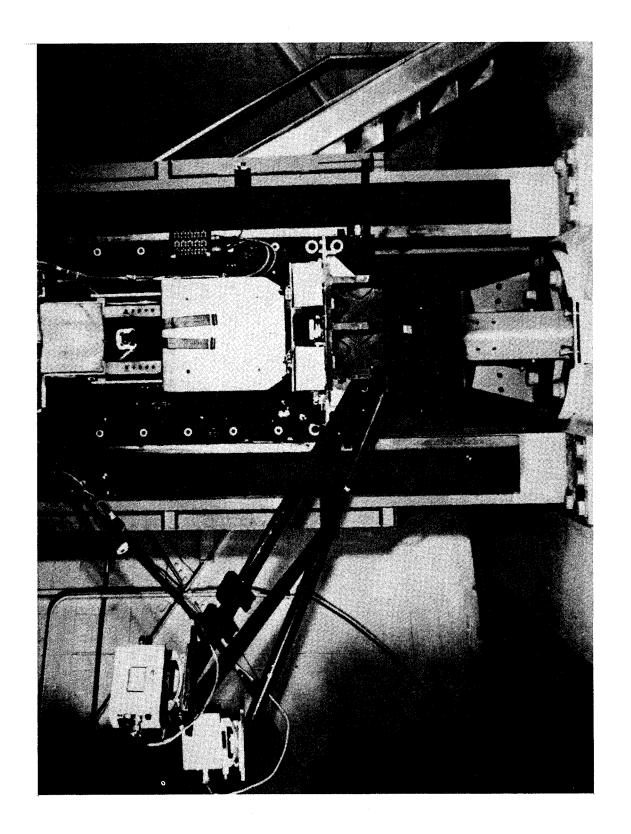
DATES: 14 JUL 86 - 14 AUG 86 RUN NUMBERS: 1127-1214 FACILITY: VERTICAL DECELERATION TOWER

ALL SENS. IN uv/lb MOTES K CHANGE +.7 0 5.78 5.61 DATE * SENS POST-CAL 26AUG86 5.78 5.57 DATE * SENS PRE-CAL 92UL86 SERIAL 20 Y 20 X TRANSDUCER MFG. 1 HODEL GM 3D-SW ε SHOULDER LOAD Y SHOULDER LOAD Z DATA POINT

SEPTERRER 1985

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TABLE A-2d: TRANSDUCER PRE- AND POST-CALIBRATION (4 OF 4)



A-19

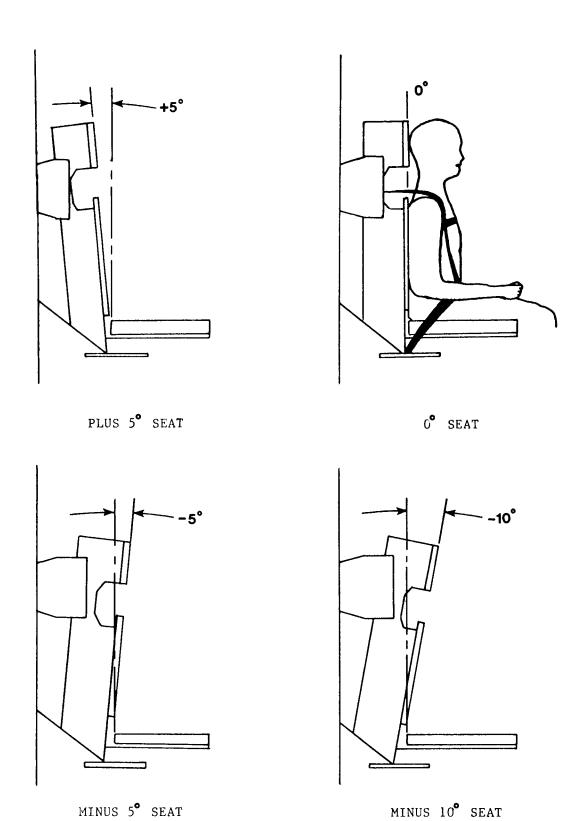


FIGURE A-2: VIP SEAT POSITIONS

A-20

	DESCRIPTION	DIMENSI	ONS IN CE	NTIMETERS
		<u>*</u>	⊻	2
*1	SEAT REFERENCE POINT	0.00	0.00	0.00
2	CENTER SEAT LOAD	+11.75	0.00	-7.94
3	RIGHT SEAT LOAD	+40.64	+17.78	-7.94
4	LEFT SEAT LOAD	+40.64	-17.78	-7.94
5	LEFT LAP LOAD	-3.81	-22.86	-4.29
6	RIGHT LAP LOAD	-3.81	+22.86	-4.29
**7	SHOULDER STRAP LOAD	-14.67	0.00	+70.17
8	CENTER SEAT LINK	+17.78	+5.08	-9.45
9	RIGHT SEAT LINK	+20.32	+12.70	-9.45
10	LEFT SEAT LINK	+20.32	-12.70	~9.45

- * All dimensions are referenced to the seat reference point (SRP). The seat reference point is located at the intersection of the horizontal seat plate (x axis) center line and the vertical back plate (z axis) center line.
- Dimensions shown are for the seat in the zero degree position. x and z measurements varied for each different seat position.

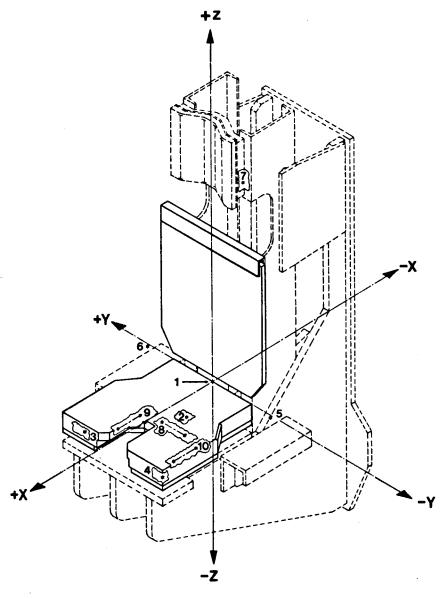


FIGURE A-4: LOAD TRANSDUCER LOCATIONS

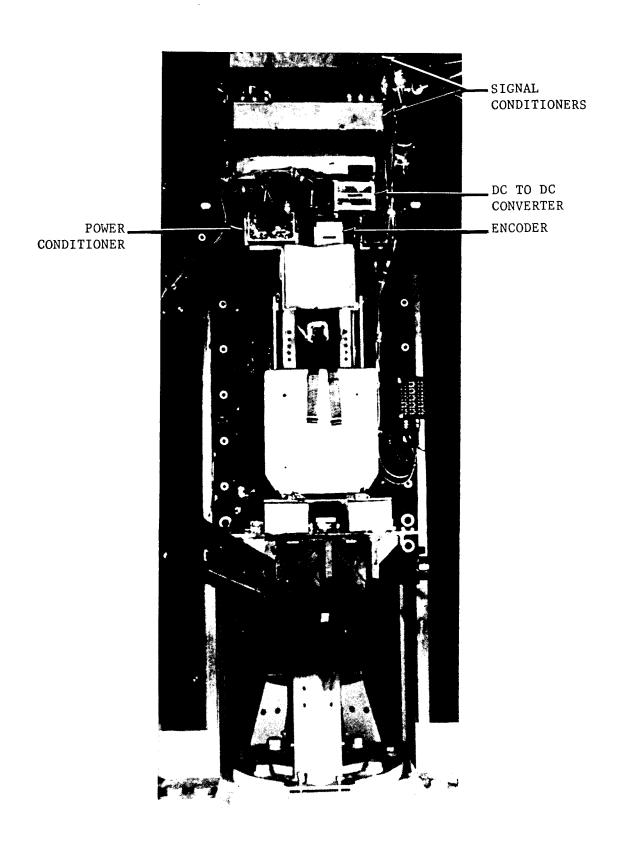


FIGURE A-6: ADACS INSTALLATION

A-22

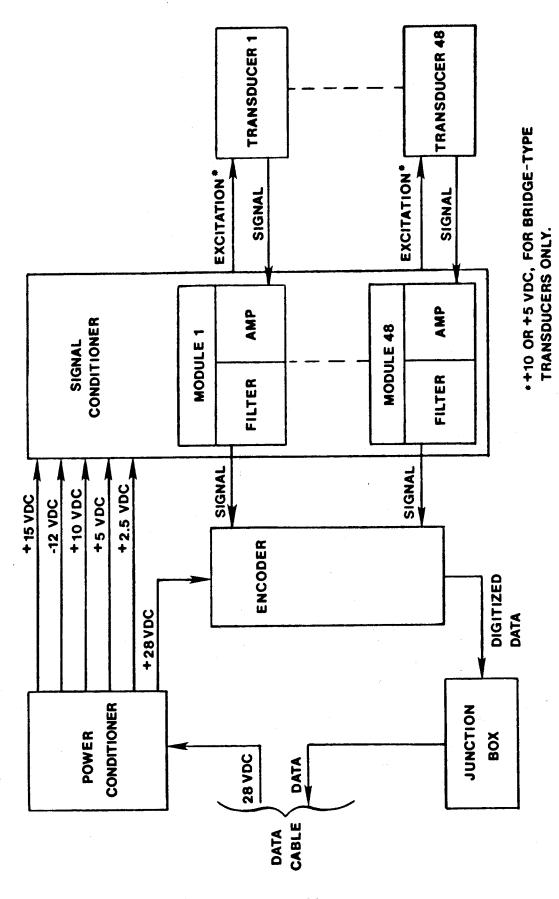


FIGURE A-7: AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM

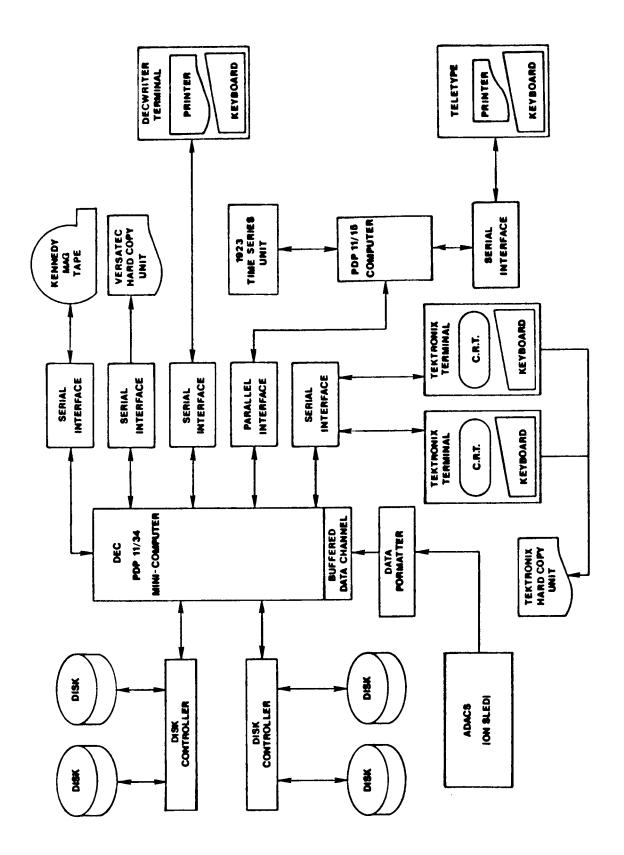


FIGURE A-8: DATA ACQUISITION AND STORAGE SYSTEM BLOCK DIAGRAM

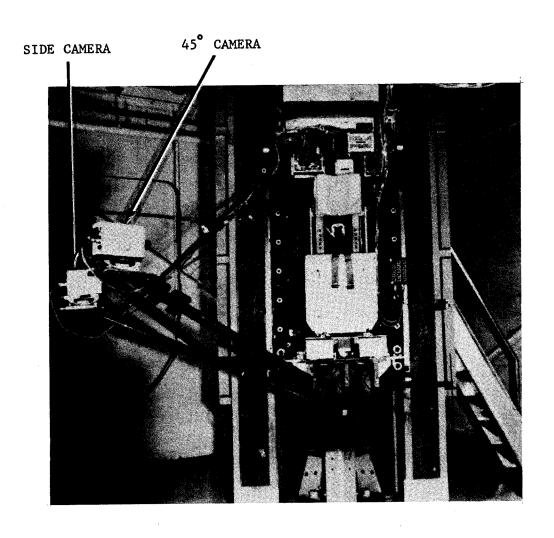
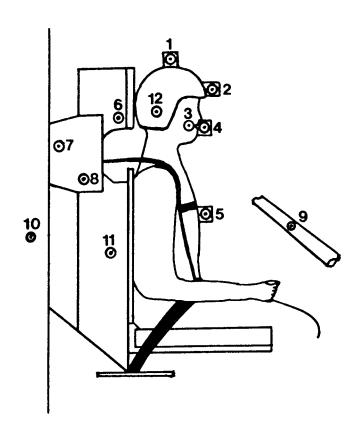


FIGURE A-9: ONBOARD CAMERA LOCATIONS



* Fiducial target locations 6, 8 and 11 vary with respect to seat back angles. Below are x, y and z dimensions for seat back angles of +5, -5 and -10 degrees.

	DESCRIPTION	DIMENS	IONS IN FEE	т		DESCRIPTION	DIMENS	IONS IN FEE	T
		×	¥	<u>z</u>		6 HEAD REST	<u>*</u> -0.4465	⊻ +0.5531	<u>z</u> +2.6823
1	UPPER HELMET	-	-	-	+5 [©]	8 LOWER PLATE	-0.6693	+0.6663	+1.7813
2	FRONTAL HELMET	-	-	-		11 SIDE RAIL	-0.6099	+0.5635	+0.9318
3	CHEEK POINT	-	-	-					
4	MOUTH PACK	-	-	-		6 HEAD REST	+0.0230	+0.5531	+2.7161
5	CHEST PACK	-	-	-	-5 ⁰	8 LOWER PLATE	-0.6726	+0.6689	+1.7729
* 6	HEAD REST	-0.2146	+0.5531	+2.7028		11 SIDE RAIL	-0.4423	+0.5635	+1.0214
7	UPPER PLATE	-1.1780	+0.6846	+2.1052					
* 8	LOWER PLATE	-0.6779	+0.6637	+1.8198		6 HEAD REST	+0.2618	+0.5531	+2.7036
9	CAMERA STRUT	+1.7294	+2.3987	+2.2508	-1c ^O	8 LOWER PLATE	-0.6654	+0.6689	+1.7969
10	CARRIAGE	-1.3238	+0.6429	+0.9167		11 SIDE RAIL	-0.3580	+0.5635	+1.0531
*11	SIDE RAIL	-0.5273	+0.5635	+0.9807					
12	CENTER HELMET	-	-	-		All dimensions are (SRP). The seat resection of the horiand the vertical bases.	ference poin zontal seat	t is locate plate (x ax	d at the inter-

FIGURE A-10: FIDUCIAL TARGET LOCATIONS

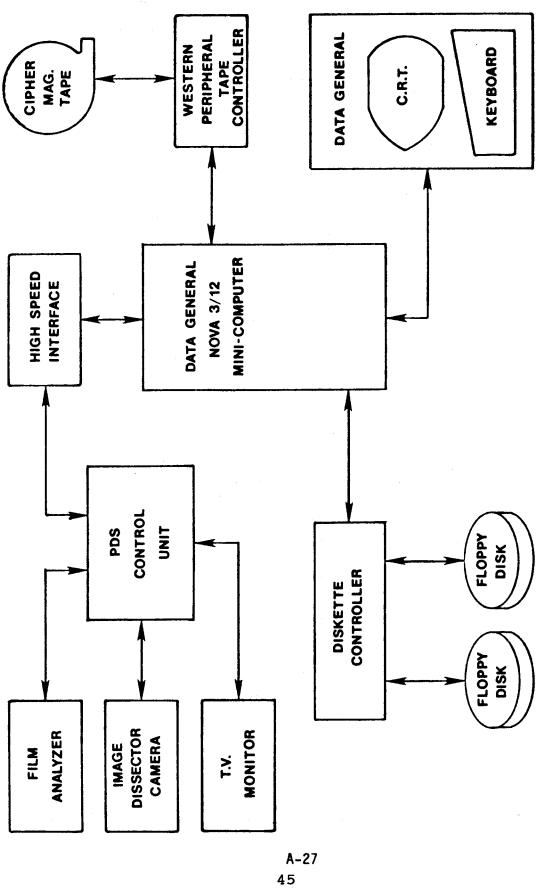


FIGURE A-11: AUTOMATIC FILM READER

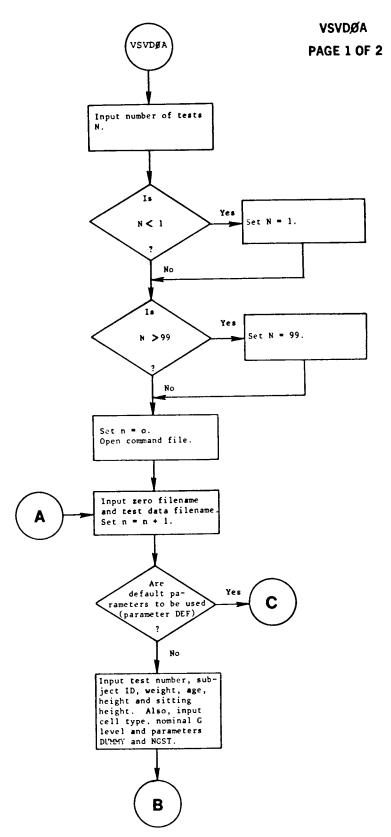


FIGURE A-12a: PROGRAM FLOWCHART FOR VSVDØA

VSVDØA PAGE 2 OF 2

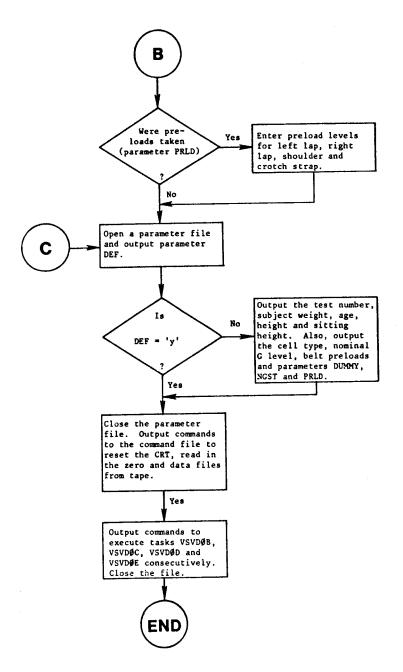


FIGURE A-12b: PROGRAM FLOWCHART FOR VSVDØA

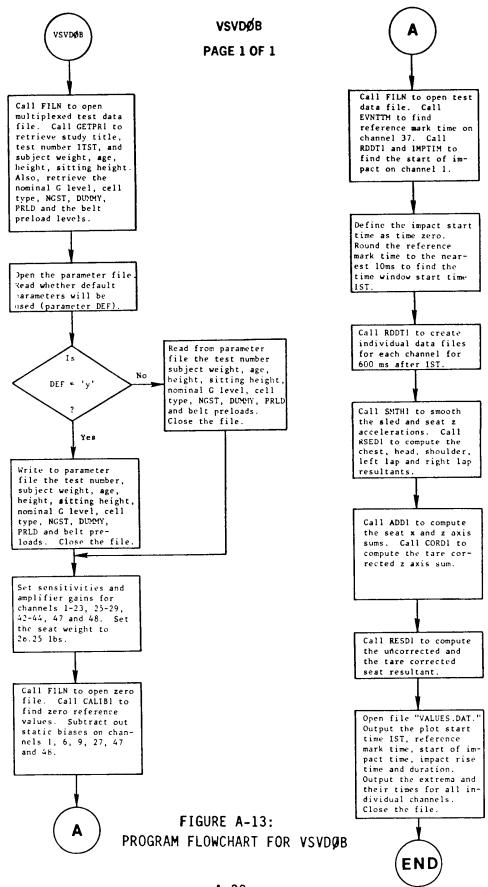
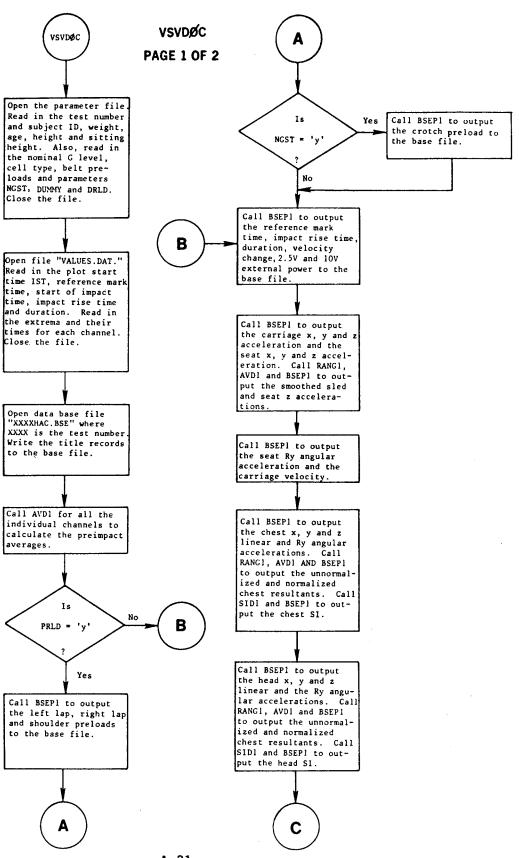


FIGURE A-14a: PROGRAM FLOWCHART FOR VSVDØC



A-31

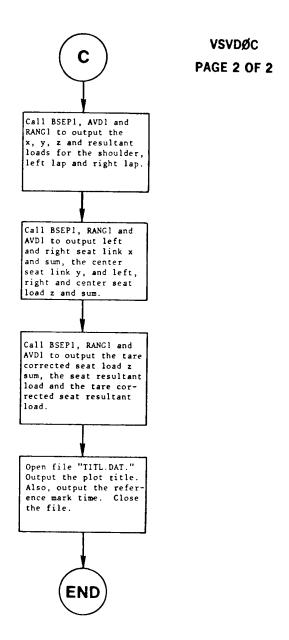
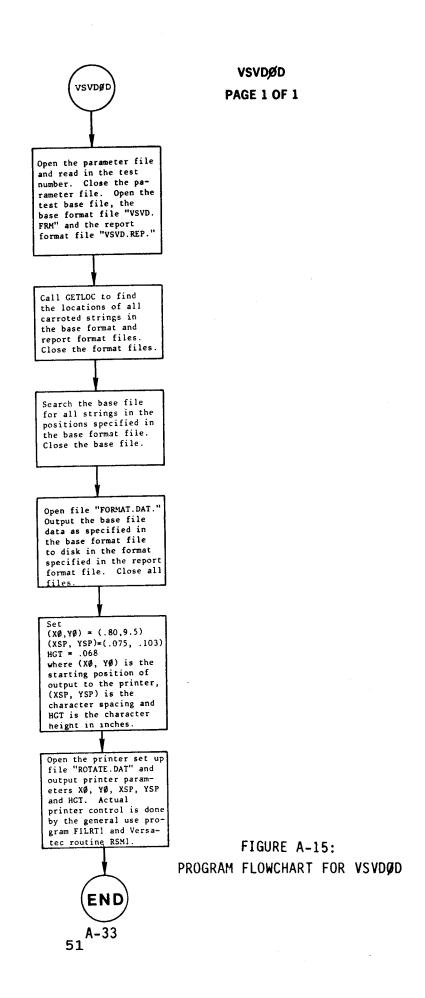


FIGURE A-14b: PROGRAM FLOWCHART FOR VSVDØC



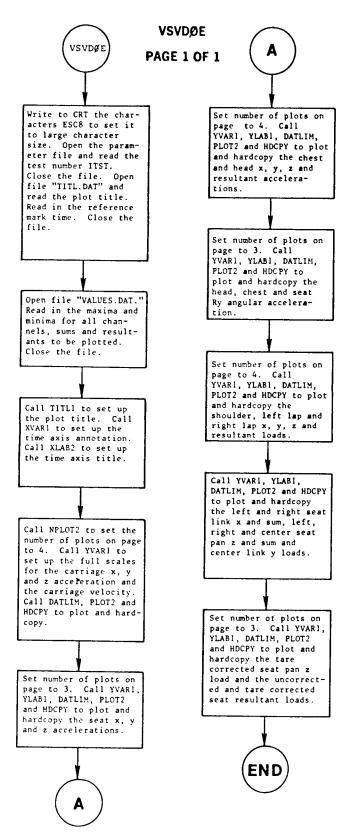


FIGURE A-16: PROGRAM FLOWCHART FOR VSVDØE

ADDENDUM

TEST CONFIGURATION AND

DATA ACQUISITION SYSTEM FOR THE

EFFECTS OF SEAT CUSHIONS AND SEAT BACK

ANGLE ON HUMAN RESPONSE DURING +Gz

IMPACT ACCELERATION

TEST PROGRAM

Prepared under Contract F33615-86-C-0531

PHASE II

Prepared by Marshall Z. Miller

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AAMRL Division

Building 824, Area B

Wright-Patterson AFB, Ohio 45433

June 1987

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INTRODUCTION

This report was prepared by DynCorp (formerly Dynalectron Corporation) for the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL/BBP) under Air Force Contract F33615-86-C-0531.

The information provided herein describes all of the instrumentation, calibration, seat cushion and processing program changes of Phase II (when compared to Phase I) of the Effects of Seat Cushions and Seat Back Angle on Human Response During +Gz Impact Acceleration Test Program. Where identical requirements exist for both Phases I and II of the test program, these requirements will not be described herein. One hundred forty-five tests were conducted for Phase II during November and December 1986 and January 1987 on the Vertical Deceleration Tower test facility.

This report is to be used as an addendum to the DynCorp November 1986 test report for Phase I of the Effects of Seat Cushions and Seat Back Angle on Human Response During +Gz Impact Acceleration Test Program.

1. INSTRUMENTATION CHANGES

The instrumentation changes as required by the Phase II Test Plan will be detailed in this section if they were different than required by the Phase I Test Plan. Identical instrumentation as required by both test plans will not be discussed.

Tables A-3a through A-3c list all of the measurement instrumentation used in Phase II of the test program. These tables designate the manufacturer, type, serial number, sensitivity and other pertinent data on each transducer used. Table A-4 lists the manufacturers' typical transducer specifications.

Human head accelerations were measured using three Endevco Model 7264-200 linear accelerometers and one Endevco Model 7302A angular (Ry) accelerometer in Phase II. The Endevco Model 2264-200 linear accelerometers used in Phase I are more prone to temperature drift and offset caused by wiring deflection. The angular accelerometer was not changed. Figure A-17 illustrates the human head acceleration package.

Human thoraxic accelerations measured in Phase II of the test program was not required to be measured in Phase I. Human thoraxic accelerations were measured using two Entran Model EGAXT-100 linear accelerometers for x and z accelerations and one Entran Model EGAXT-250 linear accelerometer for y accelerations. The accelerometers were mounted on a one inch diameter by 1/8 inch thick acrylic plastic pad and were attached to the subjects' intervertebral space between T-4 and T-5 with double-backed tape. Figure A-18 illustrates the human thoraxic acceleration package.

2. SEAT CUSHIONS

The Aces II seat cushion was the only one tested during Phase I of the test program. Figure A-19 illustrates the Aces II seat cushion installed on the VIP seat fixture.

Phase II of the test program included testing the Aces II, Operational F-4 and the Confor Foam F-4 seat cushions.

The Operational F-4 seat cushion uses a double layered contoured foam cushion with a contoured survival kit lid. Figures A-20 and A-21 illustrate the Operational F-4 seat cushion.

The Confor Foam F-4 seat cushion uses a single layer flat foam cushion with a flat survival kit lid. Figures A-22 and A-23 illustrate the Confor Foam F-4 seat cushion.

3. CALIBRATION

Calibrations were performed before and after testing to confirm the accuracy and functional characteristics of the transducers. Pre-program and post-program calibrations for Phase II of the test program are given in Tables A-5a through A-5d.

4. PROCESSING PROGRAMS

The Fortran processing programs that were developed to process the test data for Phase I of the test program are called "VSVDOA," "VSVDOB," "VSVDOC," "VSVDOD," and "VSVDOE." These processing programs were modified for Phase II of the test program to include current transducer sensitivities and the human thorax x, y, z and resultant accelerations.

		DIGITAL	TAL INS	INSTRUMENTAT	₹	REQUIREMENTS			3	'		E		
PROGRAM	A THE EFF! ANCLES !	THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING 462 ACCELERATION (PHASE 11 VENTICAL DECELERATION TOWER	ACCELERATION TOWER	AND SEAT ION (PHAS		DATE 21 NOV 86		THRU 1359) o we		IVAX	ECT.	Z	CORPORATION
DATA	DATA	XDUCER MFG & TYPE	*/*	XDUCER	EACITE V CHAN	FILTER	GAIN S/N	RAMPLE RATE FORMAT	F.S. SENS	FILTER	XDUCEN ZENO AANGE	BALANCE RALANCE RESISTORS	BRIDGE COMPLETION RESISTONS	SPECIAL NOTATIONS
-	CARR JAGE	ENDEVCO 2262A-200	FR42	4.196 av/G	10.00	09	25 29	1K	23.8 G	120	2.5	375K -in Gd.	1	
2	CARRIAGE X	ENDEVC0 2264-200	BX17	2.759 mv/G	10.00	60	100	IK 1	9.06 G	120	2.5	43K +in Gd.	1.58K	
3	CARRIAGE Y	ENDEVCO 7264-200	вн97н	2.783 mv/G	10.00	609	7 001	JK 1	9.0 C	120	2.5		1.5K	
7	неар х	ENDEVCO 7264-200	визвн	2.592 mv/G	10.00	7 09	50 23	1K 1	19.3 G	120	2.5		1.5K	
2	нело ч	ENDEVCO 7264-200	внеон	2.814 =v/C	10.00	3 /	20 22	K	17.8 G	120	2.5	-	1.5K	
9	HEAD Z	ENDEVCO 7264-200	вн63н	2.492 m v/G				1K 1	40.1 G	120	2.5		1.5K	
,	CHEST X	ENDEVCO 2264-150	BC26	2.795 mv/G	10.00	609	208	IK 1	17.9 G	120	2.5	1.2M -in Gd.	1.65K	
•	CHEST Y	ENDEVCO 2264-150	BB13	2.435 mv/G	10.00	8 09	100	IK 1	10.3 G	120	2.5	ł	1.65K	
6	CHEST Z	ENDEVCO 2264-150	2 A 20	2.629 mv/G	10.00	6 09	25 34	IK 1	38.0 G	120	2.5	156K in Gd.	1.65K	
10	LEFT SEAT LOAD	STRAINSERT FL2.5u- 2SPKT	T 3294-1	8.02 uv/1b	10.00	60 10	201	1K 1	1551 16	120	2.5	•	1	
=	RIGHT SEAT LOAD	STRAINSER FL2.5u- 2SPKT	T 3294-2	8.03 uv/1b	10.00	60	201	IK 1	1550 16	120	2.5	Į.	ı	
12	CENTER SEAT LOAD	STRAINSER FL2.5u- 2SPKT	7 3294-4	8.08 uv/1b	10.00	60	100	Ĭ,	3094 15	120	2.5	ı	,	
13	LEFT LOAD	M/DYN EA06-062 TJ-350	2	10.32 uv/1b	10.00	60 13	402	IK 1	603 1b	120	2.5 0.0 0.0	1	3	
14	RICHT LOAD LINK X	MM/DYN EA06-062 IJ-350	3	10,68 uv/1b	10.00	60	402	1,4	582 lb	120	2.5 0.6 0.6	24K in Gd.	1	
											. !	CELL A-H CELL 1 SE	CELL A-H SEAT WEICHT CELL I SEAT WEICHT CELL J SEAT WEICHT	r - 28.25 lb - 29.75 lb - 27.5 lb PAGE 1 OF 3

TABLE A-3a: INSTRUMENTATION REQUIREMENTS

		DIG.	DIGITAL INS	INSTRUMENTATIO	z	REQUIREMENTS	MENTS						'	
FACILITY	A THE EP	THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING 4CZ ACCELERATION (PHASE II) VERTICAL, DECELERATION TOWER.	ACCELERA TION TOWE	NA AND SEA	T BACK SE II)	DATE 21 NOV 86	NOV 86 5	THRU_15_JAN 87	JAN 87	Ħ	XNAI	LECT	RON	Dynalectron () corporation
DATA	DATA POINT	X DUCER	8/8	XDUCER	EXCITE	FRTER	QVIN QVIN	ATTE STANFA	F.S. SENS	FILTER	XDUCER	BALANCE	BRIDGE	SPECIAL NOTATIONS
15	LOAD X	1 1	15x	5.35 uv/1b	10.00	8 2	7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	1K	1162 1b	1	2.5	16K +in Gd.	-	
16	LEFT LAP	GH- 3D-SW	157	5.32 uv/1b	10.00	3 2	008	×	587 16	120	5. 5. 5. 5. 5.	18K +in Cd	,	
17	3 2	CI+ 3D-SW	152	6.30 uv/1b	10.00	9 2	402	×	987 16	120	2.5	¥ë	,	
18	×	GH- 3D-SW	21X	5.04 uv/1b	10.00	08.	402	=	1234 1b	120	2.5	1		
19	RIGHT LAP LOAD Y	GH 3D-SW	21.Y	4.83 uv/1b	10.00	09	800	¥ \	64.7 lb	120	2.5	17K +in Gd.	1	
20	RICHT LAP LOAD Z	СМ- 3D-6W	212	6.09 uv/1b	10.00	60 20	402 603	× -	1021 16	120	2.5	27K - in	,	
21	SHOULDER LOAD X	48-QE	202	6.30 uv/1b	10.00	60	402	X -	987 1b	120	2.5		,	
22	SHOULDER LOAD Y	CH- 3D-SW	20Y	5.81 uv/1b	10.00	60	800	¥	538 lb	120	2.5	1	,	
23	SHOULDER LOAD Z	CH- 3D-SW	20χ	5.58 uv/1b	10.00	60	402	N I	111516	120	2.5	29K +in Gd.	,	
25	SEAT X ACCEL.	ENDEVCO 2264-150	BB28	2.700 =v/G	10.00	60 25	× 20	¥/	18.5 C	120	2.5	72.4K +in Gd.	1.65K	
26	SEAT Y ACCEL.	ENDEVCO 2264-200	BV95	2.981 mv/c	10.00	92 09	50 21	X -	16.8 G	120	2.5	372K +in Gd.	1.47K	
27	SEAT Z ACCEL.	ENDEVCO 2264-200	BW07	2.824 mv/c	10.00	60	05	¥ \	17.7 G	120	2.5	294K -in Gd.	1.47K	
28	CENTER LOAD LINK Y	MM/DYN EA-06-062 TJ-350	\$	9.82 uv/1b	10.00	60 28	402	<u>=</u>	633 1b	120	2:5	ı	ı	
29	VEL. TACH.	CLOBE 22A672-2	4	.06209 V/F/S	- 29	30	-) - 	80.5 FT/SEC	09	0.0 0.0 0.0	1	,	
													i	PAGE 2 OF 3

TABLE A-3b: INSTRUMENTATION REQUIREMENTS

PROGRAM	THE EFFE	DIGI CTS OF SEA URING +CZ	DIGITAL INSTRUMENTATION THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING -62 AUCHLERATION (PHASE II)	INSTRUMENTATION HION AND SEAT BACK ERATION (PHASE II)	Z	DATE 21 NOV 86			15 JAN 87	Ω	YNAL	ECTE	NO	DYNALECTRON (CORPORATION
FACILITY	VERTICAL	DECELERA!	TION TOWER			RUN 1215		THE 0 1339						
DATA CHAMMEL	DATA	XDUCER MFG A TVPE	*/8	KDUCEA	EXCITE	FILTER SERIES S/R	N/R 0 A IN P	SAMPLE NATE FORMAT	f.s. 36ms	FILTER	XDUCER ZENO ZENO RAMOE	BRIDGE BALANCE RESISTORS	SANDAE COMPLETION RESISTORS	SPECIAL MOTATIONS
30	DUMMY HEAD X	ENDEVCO 2264-200	сн74	2.939 mv/G	10.00	09	50	1 1	17.0 G	120	2.5.5.0	190K +in Gd.	1.65K	
31	DUMMY HEAD Y	ENDEVCO 2264-200	BQ4.2	2.740 =v/G	10.00	60	50 8	1K 1	18.2 G	120	00	220K +in Gd.	1.65K	
32	DUMMY HEAD 2	ENDEVCO 2264-200	СИ70	2.676 mv/c	10.00	60	25 18	1K 1	37.4 G	120	2.5	80K +in Gd.	1.65K	
33	DUMMY HEAD ANG	ENDEVCO 7302	A150	8.26 uv/gAD/ SEC	10.00	60	100	11/1	3027 RAD/SEC ²	120	2.5.5.0	1	1	
34	THORAX	ENTRAN EGAXT-100	1206S- L1-1		10.00	γ _ε 09	100	1 1 1	24.9 G	120	2.5	1	1	
35	THORAX	ENTRAN EGAXT-250	129 6s-L 14-14	.500 /G	10.00	60 35	201	11 1	24.9 G	120	2.5	١	ı	
36	THORAX 2	ENTRAN BGAXT-100	29T6U-A 18-18	1.019 mv/G	10.00	96 36	50 26	11.	49.1 G	120	2.5	ı	•	
37	EVENT	1	-	1	18	1000	2.5	111	5.0 Volt	2000	5.0	1	1	
38	T=0 PULSE	1	1	ı	38	1000		1 K 1	5.0 Volt	2000	0.6	ı		
42	HEAD RY ANCULAR	ENDEVCO 7302A	AB12	4.20 uv/gAb/ SEC	10.00	60		IK 1	2961 RAD/SEC ²	120	2.5	ı	١	
43	CHEST RY ANGULAR	ENDEVCO 7302A	AB15	6.76 uv/g/D/ SEC	10.00	60 43	201	IK 1	1840 RAD/SEC ²	120	2.5	450K -in Gd.	ı	
75	SEAT RY ANGULAR	ENDEVCO 7302B	7 7 T d	3.732 uv/BAD/ GEC	10.00	09	12	¥	1666 RAD/SEC ²	120	2.5	ı	,	
47	2.5 Volt Bias	1	ŀ	1	- 41	180	-\	ĭ	2.5 Volt	360	2.5	ı	1	
87	10 Volt Exc.	1	1	1	- 84	180		¥	2.5 Volt	360	2.5	1	1	
														PAGE 3 OF 3

TABLE A-3c: INSTRUMENTATION REQUIREMENTS

TYPICAL TRANSDUCER SPECIFICATIONS

	eter	eter.	eter	eter,	reter,	eter,	eter,	ter;	ter:	ax exc.; ange
ADDITIONAL NOTES	Linear accelerometer	Linear accelerometer	Linear accelerometer 1000 G overrange	Linear accelerometer, .7 damping ratio	Angular Accelerometer, X10 overrange; housing connector	Angular accelerometer, X10 overrange	Angular accelerometer, X10 overrange	Linear accelerometer; 10 KG overrange, .7 damping ratio	Linear accelerometer; 10 KG overrange, .7 damping ratio	Load cell; 15 V max exc.; 5 K LB max. overrange
2 ARM or 4 ARM	2 arm	2 arm	2 arm	4 arm	4 arm	4 arm	4 arm	4 arm	4 arm	4 arm
- EXCITATION (Volt)	임	10	01	01	10	10	10	10	10	10
FREQUENCY RESPONSE (Hz.)	0-800	0-1200	0-1000	0-1800	1-600	1-600	1–600	0-800	0-1000	0-2000
RESONANCE FREQ (Hz)	3400	4700	0009	0002	2250	2500	3000	1700	2000	3600
SENSITIVITY (mr)	2.5/6	2.5/6	2.5/6	2.5/6	.006 /Rad/Sec2	.055 /Rad/Sec2	.004 /Rad/Sec2	2.0/G	1.0/6	.008/Lb
RANGE	±150 G	±200 G	±200 G	£200 G	±50,000 Rad/Sec2	±50,000 Rad/Sec2	±50,000 Rad/Sec2	±100 G	1 250 G	±2500 Lb
R MODEL	2264-150	2264-200	7264-200	2262A-200 ±200	7302	7302A	73028	EGAXT-100 ±100	EGAXT-250 ±250	
MANUFACTURER	Endevco	Endevco	Endevco	Endevco	Endevco	Endevco	Endevco	Entran	Entran	Strainsert FL2.5U- 2SPKT

TABLE A-4: TYPICAL TRANSDUCER SPECIFICATIONS

FACILITY: VERTICAL DECELERATION TOWER PROGRAM: VSBA II

DATES: 21 NOV 86-15 JAN 87

RUN NUMBERS: 1215-1359

	GJJINJN4G4	191839	PRE-CAL	CAL	POST-CAL	CAL		
DATA POINT	MFG. & HODEL	NUMBER	DATE	SENS	DATE	SENS	& CHANGE	MOTES
CARRIAGE Z	ENDEVCO 2262A-200	FR42	18NOV86	4.196	4.196 20JAN87	4.171	9.–	
CARRIAGE X	ENDEVCO 2264-200	BX17	18NOV86	2.759	20JAN87	2.779	+.7	
CARRIAGE Y	ENDEVCO 7264-200	вн97н	18NON81	2.783	20JAN87	2.781	1	
неар х	ENDEVCO 7264-200	вн58н	вн58н 18NOV86	2.592	2.592 21JAN87	2.595	+.1	
неар х	ENDEVCO 7264-200	вн6он	18NOV86	2.814	2.814 21JAN87	2.803	4	
неар 2	ENDEVCO 7264-200	внезн	вн63н 18NOV86	2.492	2.492 21JAN87	2.492	0	
СНЕST X	ENDEVCO 2264-150	BC26	140CT86	2.795	2 LJAN87	2.792	1	
снезт х	ENDEVCO 2264-150	BE13	150CT86	2.435	2.435 21JAN87	2.443	+.3	
CHEST 2	ENDEVCO 2264-150	2A20	150CT86	2.629	2.629 21JAN87	2.664	+.2	
								All sensitivities in units of mv/G

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TABLE A-5a: TRANSDUCER PRE- AND POST-CALIBRATION

PROGRAM: VSBA II

DATES: 21 NOV 86-15 JAN 87

RUN NUMBERS: 1215-1359

FACILITY: VERTICAL DECELERATION TOWER

			-344	PRE-CAL	POST-CAL	145		
DATA POINT	TRANSDUCER NFG. & HODEL	NUMBER	DATE	SENS	DATE	SENS	& CHANGE	MOTES
LEFT LOAD	MM/DYN EA-06-062TJ- 350	2	13NOV86	10.32	15JAN87	10.35	+.3	
RIGHT LOAD	MM/DYN EA-06-062TJ- 350	3	13NOV86 10.68	10.68	15JAN87 10.66	10.66	2	
CENTER LOAD LINK Y	MM/DYN EA-06-062TJ- 350	2	13NOV86	9.82	15JAN87	98.6	+.4	
LEFT LAP LOAD X	GM-3D-SW	15X	13NOV86	5.35	16JAN87	5.36	+.2	
LEFT LAP LOAD Y	MS-QE-ND	15Y	13NOV86	5.32	16JAN87	5.32	0	
LEFT LAP LOAD 2	MS-3D-SW	152	13NOV86	6.30	16JAN87	6.33	+.5	
RIGHT LAP LOAD X	GM-3D-SW	21X	13NOV86	5.04	16JAN87	5.04	0	
RIGHT LAP LOAD Y	GM-3D-SW	21%	13NOV86	4.83	16JAN87	4.80	6	
RIGHT LAP LOAD 2	MS-QE-WD	212	13NOV86	60°9	16JAN87	6.05	2	
SHOULDER LOAD X	GM-3D-SW	202	14NOV86	6.30	16JAN87	6.29	2	All sensitivities in units of uv/lb

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TABLE A-5b: TRANSDUCER PRE- AND POST-CALIBRATION

FROGRAM: VSBA II

FACILITY: VERTICAL DECELERATION RUN NUMBERS: 1215-1359

TOWER

			THE-CHE	CAL	POST-CAL	Jej-		
DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL	DATE	SENS	DATE	SENS	A CHANGE	MOTES
SHOULDER LOAD Y	GM-3D-SW	20Y	14NOV86	5.81	16JAN87	5.73	-1.2	
SHOULDER LOAD 2	GM-3D-SW	20X	14NOV86	5.58	16JAN87	5.57	2	
HEAD RY ANGULAR	ENDEVCO 7302A	AB12	19NOV86 LV/RAD/ SEC	4.20 sv/RAB/ SEC	4.22 22JAN87µv/RAD/ SEC	4.22 1V/RAB/ SEC	+.4	
CHEST RY ANGULAR	ENDEVCO 7302A	AB15	6.76 19NOV86µv/RAD/ SEC	6.76 1V/RAD/ SEC	6.81 22JAN87µv/RAD/ SEC	6.81 uv/RAB/ SEC	8. +	
SEAT RY ANGULAR	ENDEVCO 7302B	PT47	3.732 22AUG86 _{1V} /RAD/ SEC	3.732 uv/RAD/ SEC	3.719 22JAN87µv/RAD/ SEC	3.719 uv/RAB/ SEC	3	
		·						
			:	,				Unless noted otherwise, all
								sens. in units of uv/lb.

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TABLE A-5c: TRANSDUCER PRE- AND POST-CALIBRATION

PROGRAM: VSBA II

DATES: 21 NOV 86-15 JAN 87

RUN NUMBERS: 1215-1359 FACILITY: VERTICAL DECELERATION TOWER

			1	PRE-CAL	1502	POST-CAL		
DATA POINT	HEG. L HODEL	NUMBER	DATE	SENS	DATE	SENS	R CHAMGE	MOTES
SEAT X ACCELERATION	ENDEVCO 2264-150	BB28	18NOV86 2.700	2.700	20JAN87 2.714	2.714	+.5	
SEAT Y ACCELERATION	ENDEVCO 2264-200	BV95	18NOV86 2.981	2.981	20JAN87 2.979	2.979		
SEAT Z ACCELERATION	ENDEVCO 2264-200	BW07	18NOV86 2.824	2.824	20JAN87 2.835	2.835	4.4	
DUMMY HEAD X	ENDEVCO 2264-200	CH74	22AUG86	2.939	21JAN87 2.943	2.943	+ 1.1	
DUMNY HEAD Y	ENDEVCO 2264-200	BQ42	22AUG86 2.740	1	21JAN87 2.736	2.736	1	
DUMMY HEAD Z	ENDEVCO 2264-200	СН70	22AUG86 2.676	}	21JAN87 2.690	2.690	+.5	
DUMMY HEAD ANGULAR	ENDEVCO 7302	A150	19NOV86 uv/gab/22JaN87 SEC	8.257 uv/RAD/ SEC	22JAN87	8.154 uv/RAD/ SEC	-1.2	
								Unless noted otherwise, all
								sens. in units of mv/G.

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TABLE A-5d: TRANSDUCER PRE- AND POST-CALIBRATION

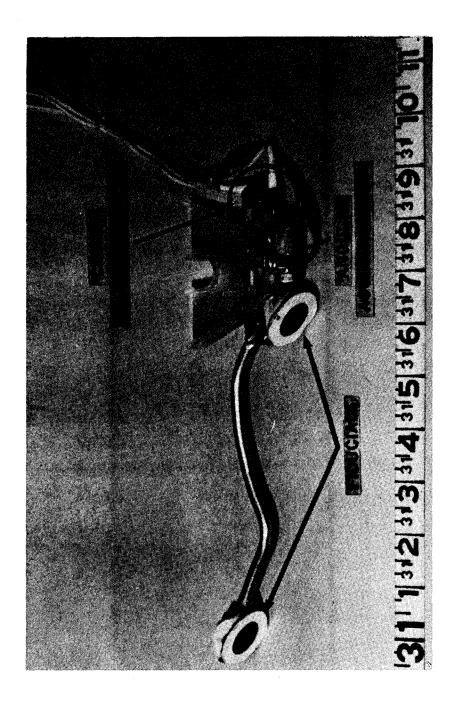


FIGURE A-17: HUMAN HEAD ACCELERATION PACKAGE



FIGURE A-18: HUMAN THORAXIC ACCELERATION PACKAGE

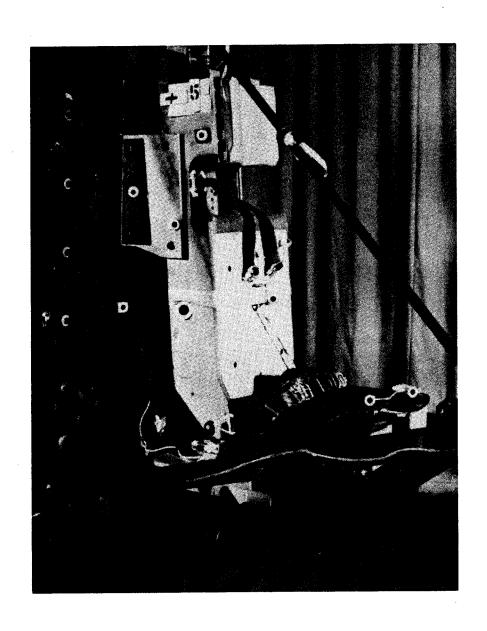


FIGURE A-19: ACES II SEAT CUSHION



A-50

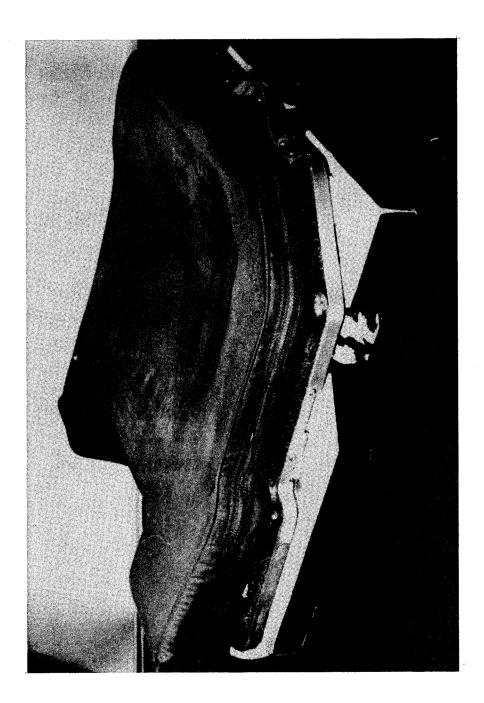


FIGURE A-21: OPERATIONAL F-4 SEAT CUSHION



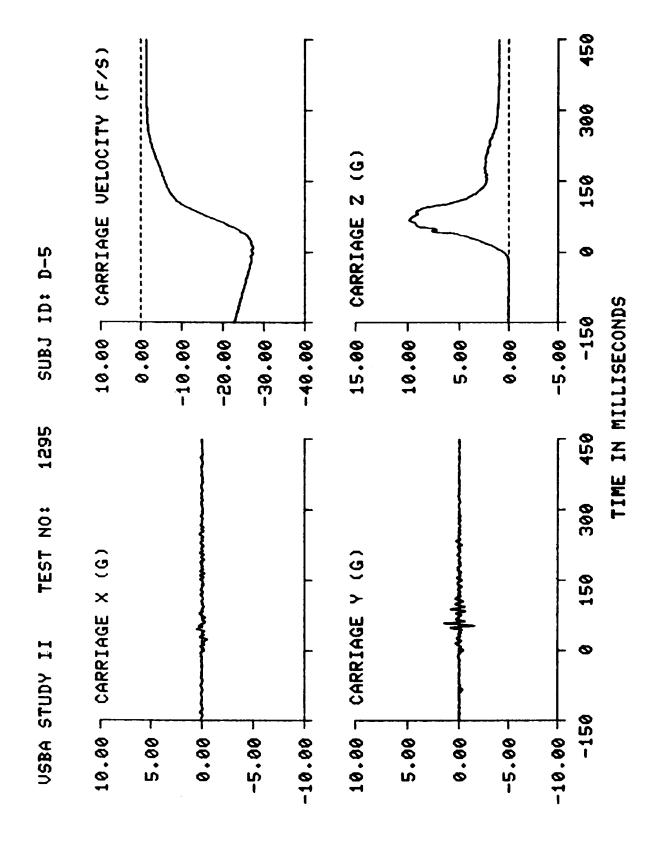
FIGURE A-23: CONFOR FOAM F-4 SEAT CUSHION

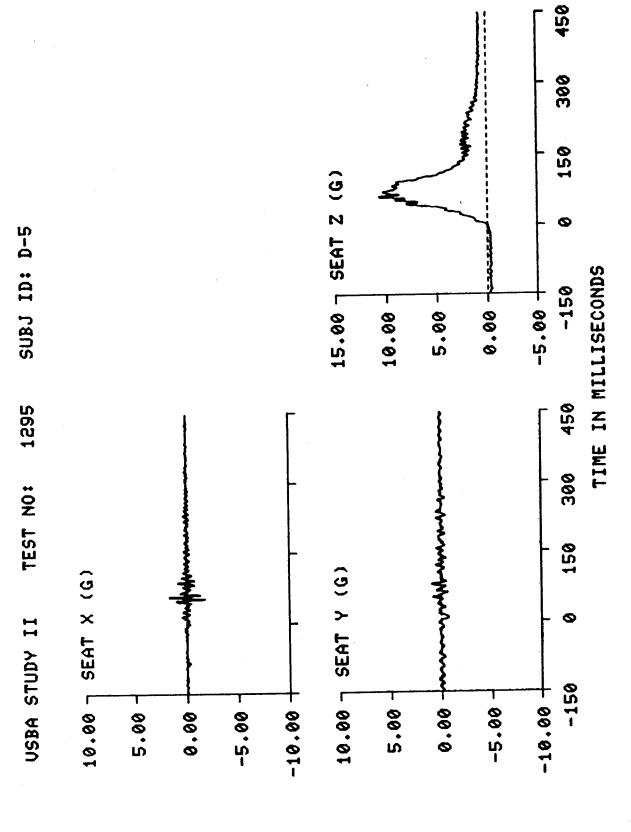
APPENDIX B

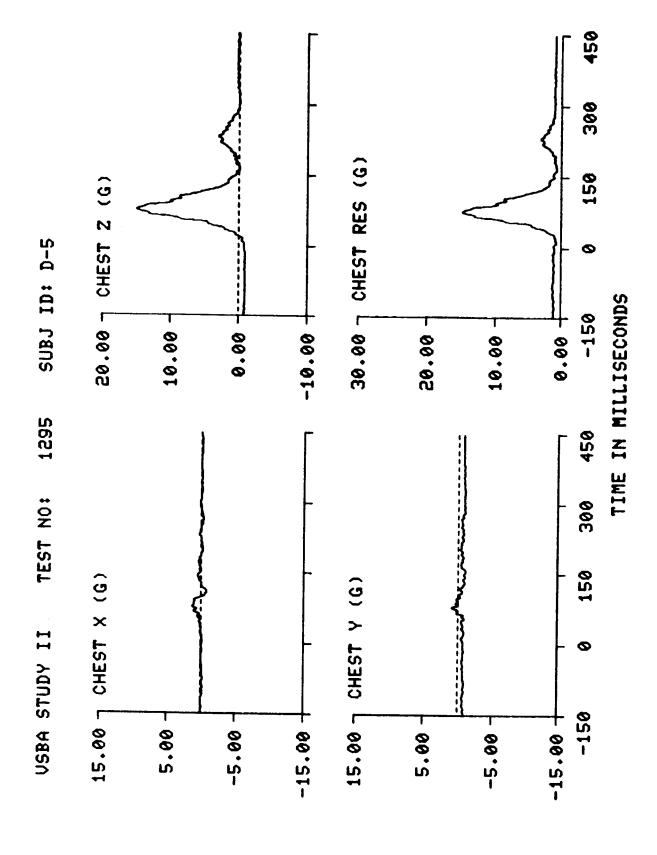
REPRESENTATIVE TEST DATA

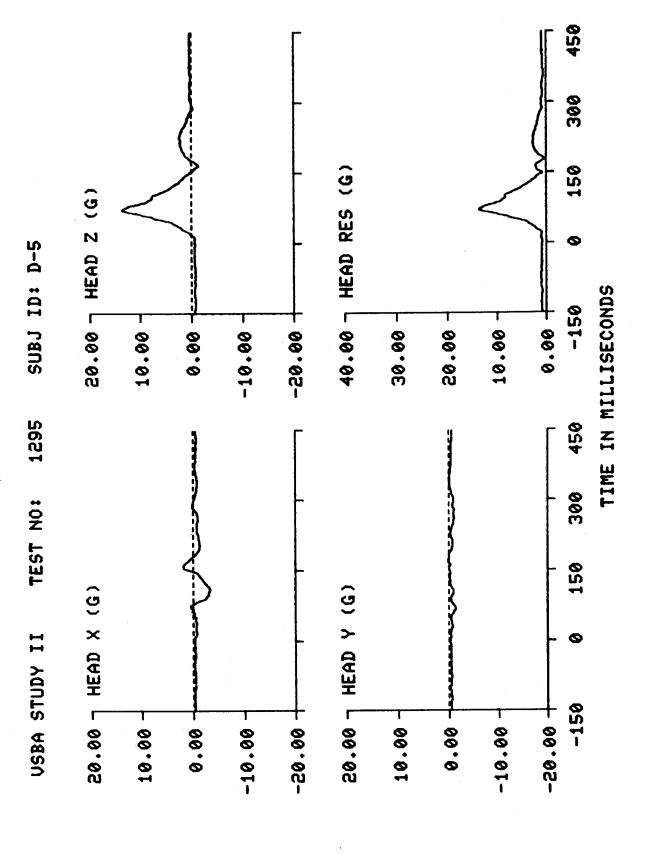
VSBR STUDY II TEST: 1295 SUBJ: D-5 WT: 172.0 NOM G: 10.0 CELL: F

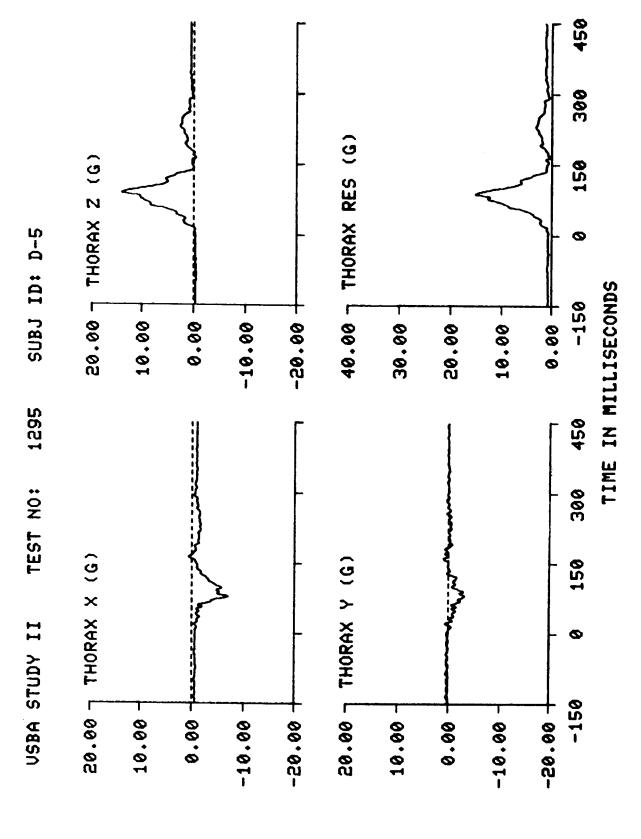
DATA ID	IMMEDIATE PREIMPACT	MAXIMUM MAXIMUM	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK 2.5V EXT PWR 10V EXT PWR		2.50 10.01	2.50 10.00	-150. 0. 1.	10. 0.
CARRIAGE ACCELERATIÓN (G) X AXIS Y AXIS Z AXIS Z AXIS (SM)	0.07 -0.03 0.05 0.07	0.53 1.44 9.86 9.65	-0.49 -1.61 0.50 0.56	44. 57. 67. 69.	23. 52. 0. 0.
SEAT ACCELERATION (G) X AXIS Y AXIS Z AXIS Z AXIS Z AXIS (SM) BY	0.05 -0.02 -0.24 -0.24 -8.26	1.69 0.91 10.72 9.89 26.72	-1.74 -0.77 0.03 0.11 -33.25	56. 79. 61. 71. 61.	52. 8. 0. 0. 65.
CARRIAGE VELOCITY (F/S)	-26.81	-1.24	-27.40	333.	9.
CHEST ACCELERATION (G) X AXIS Y AXIS Z AXIS RESULTANT NORM RESULTANT SI RY	-0.06 -0.74 -0.83 1.11 0.12	1.25 0.86 14.81 14.88 1.54 27.63 219.60	-0.78 -1.08 -0.77 0.59 0.06	76. 78. 76. 76. 76.	107. 155. 3. 170. 170.
HEAD ACCELERATION (G) X AXIS Y AXIS Z AXIS RESULTANT NORM RESULTANT SI RT	-0.35 -0.46 -0.59 0.82 0.09	1.95 0.19 13.60 13.66 1.42 22.19 161.45	-3.29 -1.44 -1.33 0.34 0.04	157. 169. 71. 71. 71. 73.	109. 67. 165. 178. 178.
THORAX ACCELERATION (G) X AXIS Y AXIS Z AXIS Z AXIS RESULTANT NORM RESULTANT	-0.59 0.17 -0.31 0.70 0.07	0.62 0.89 14.02 15.14 1.57	-6.91 -3.13 -0.45 0.08 0.01	162. 161. 88. 88.	78. 81. 164. 167. 167.
SHOULDER LOADS (LB) X AXIS Y AXIS Z AXIS RESULTANT	87.28 -2.46 2.10 87.35	125.73 7.69 38.39 129.74	33.96 -3.06 1.63 34.83	81. 215. 85. 61.	301. 4. 1. 301.
LAP LOADS (LB) LEFT X AXIS LEFT Y AXIS LEFT Z AXIS LEFT RESULTANT RIGHT X AXIS RIGHT Y AXIS RIGHT Z AXIS RIGHT Z AXIS RIGHT Z AXIS	67.79 24.48 59.45 93.45 54.99 19.81 85.09	87.01 26.40 56.56 103.13 77.85 23.35 59.10	17.29 8.78 -1.66 23.43 11.25 3.30 -0.10 16.12	98. 96. 98. 96. 99. 0.	338. 52. 60. 362. 357. 61. 61.
SEAT LÜADS (LB) LEFT LINK X AXIS RIGHT LINK X AXIS X AXIS CENTER LINK Y AXIS LEFT PAN Z AXIS RIGHT PAN Z AXIS CENTER PAN Z AXIS CENTER PAN Z AXIS Z AXIS SUM Z AXIS MINUS TARE RESULTANT RESULTANT MINUS TARE	-0.87 2.08 1.21 -2.50 46.76 37.75 100.21 184.72 219.70 184.75 219.72	1.84 8.08 8.16 -1.38 824.40 594.40 1437.98 2565.48 2337.99 2565.76 2338.30	-12.01 -26.26 -35.88 -36.83 -36.86 30.84 114.25 189.71 196.25 189.75	164. 46. 49. 274. 84. 84. 72. 78. 78. 78.	82. 92. 93. 72. 360. 320. 322. 322. 322.

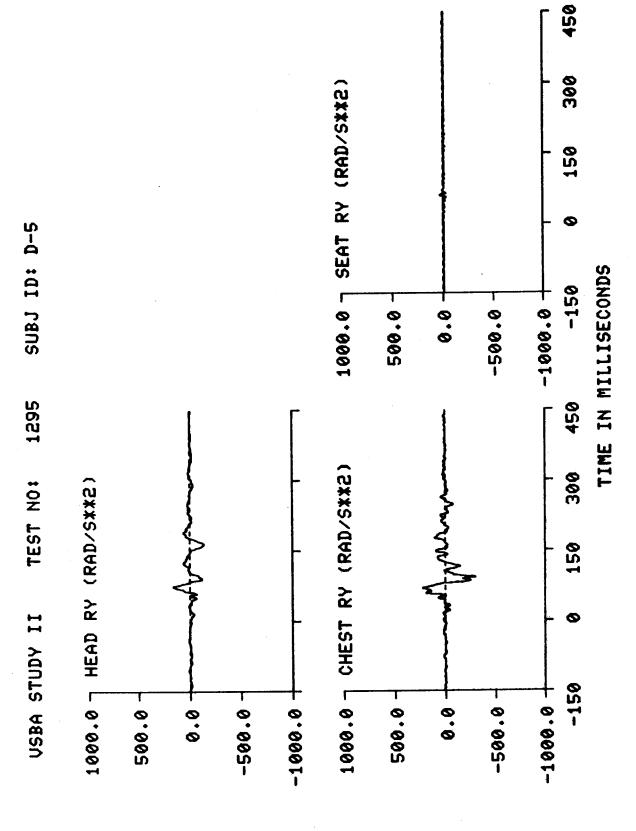


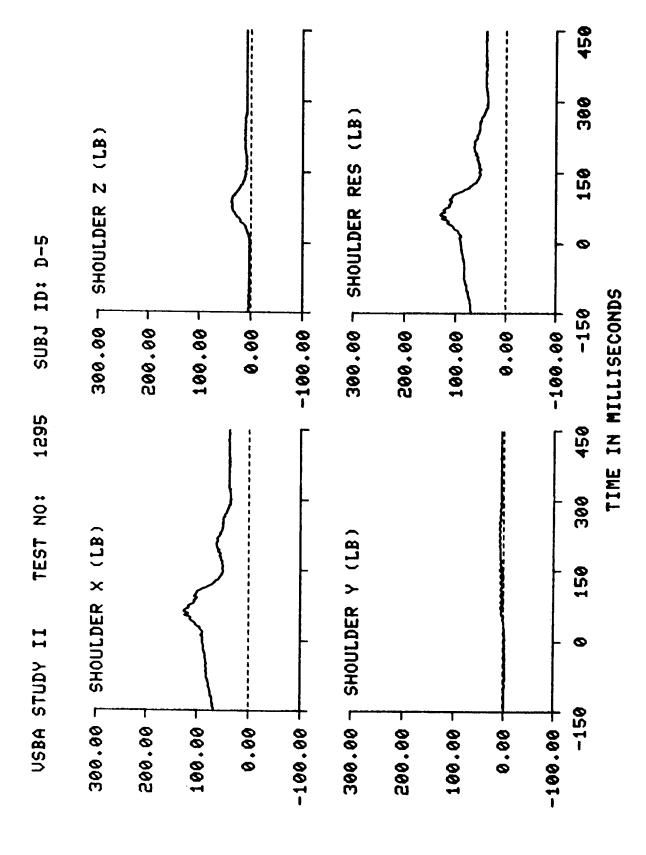


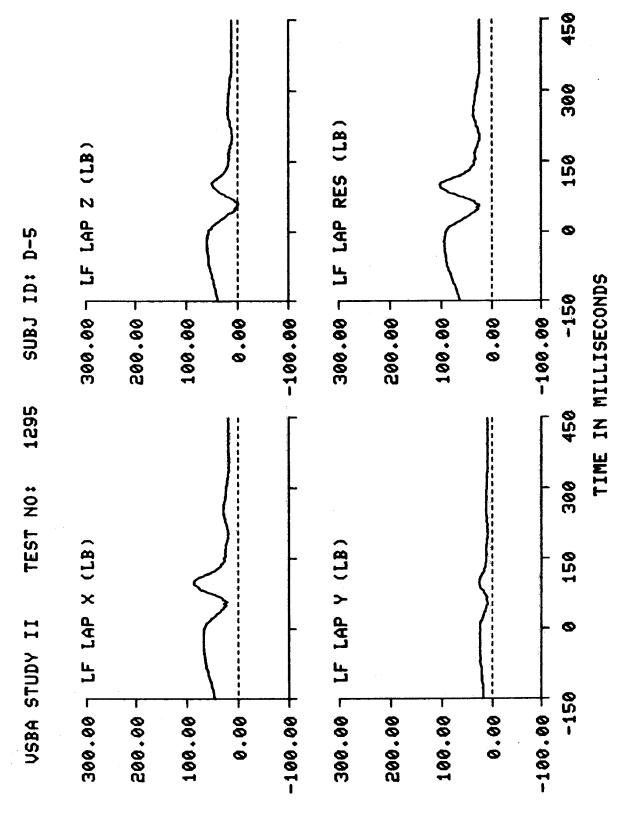


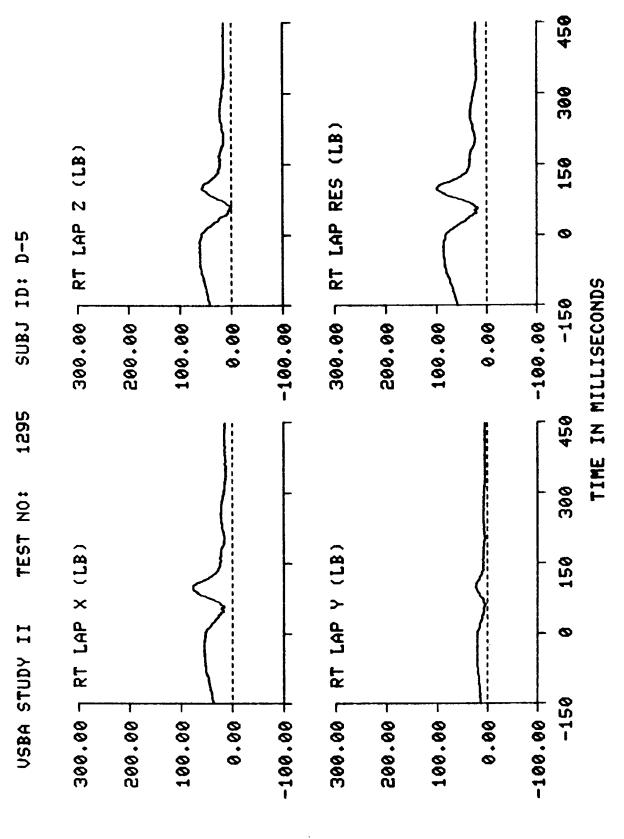


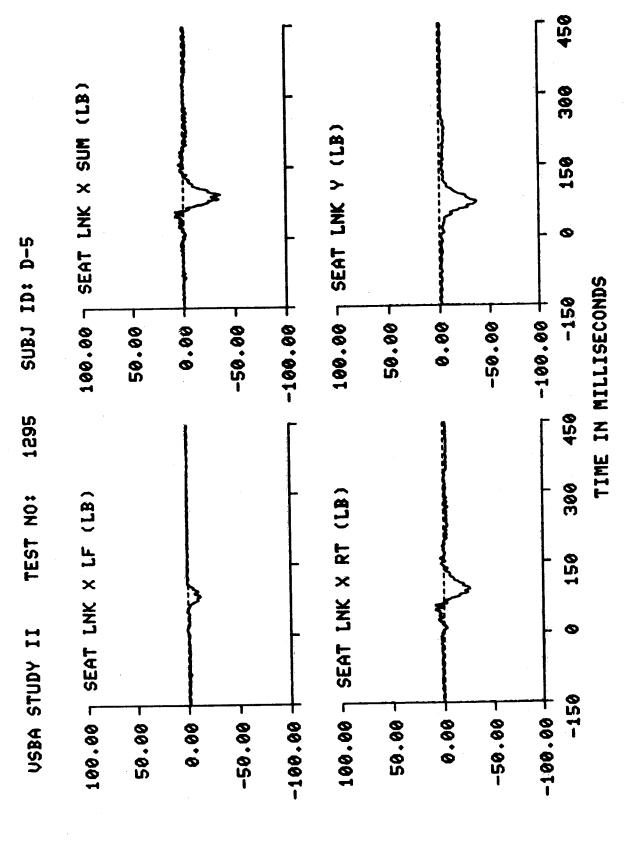


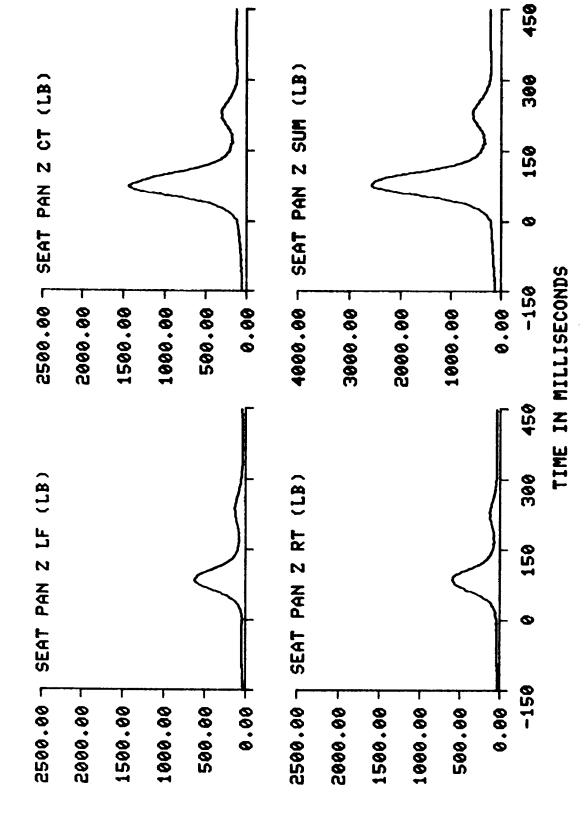










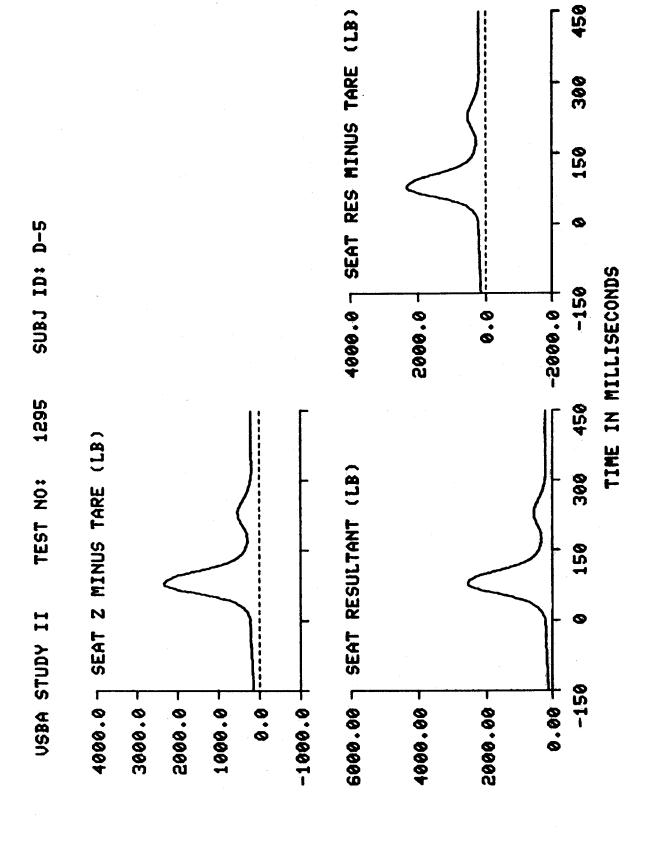


SUBJ ID: D-5

1295

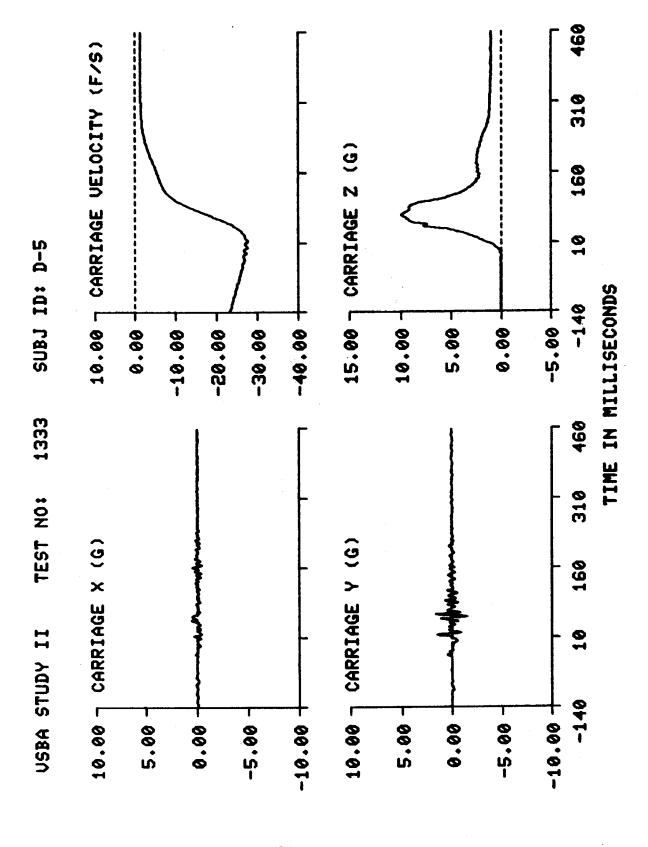
TEST NO:

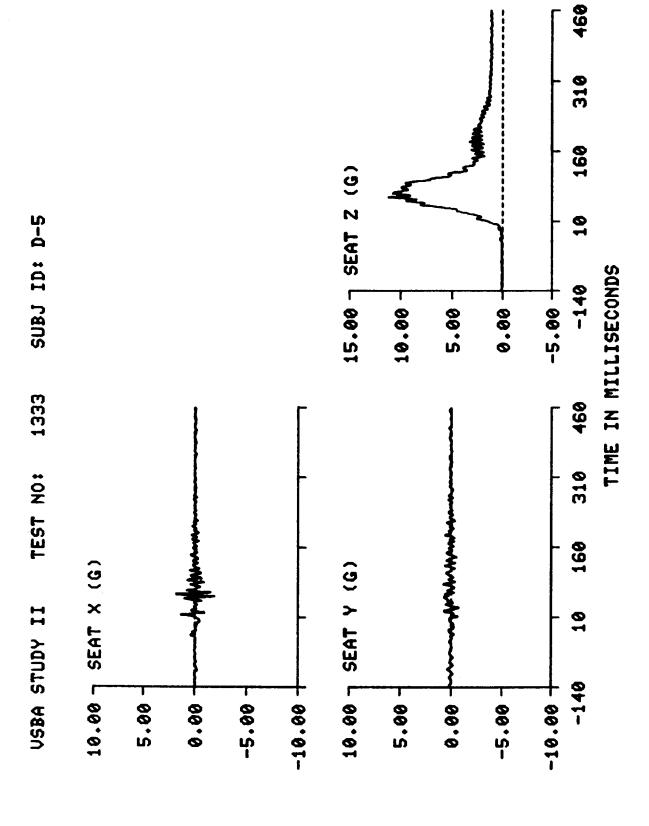
USBA STUDY II

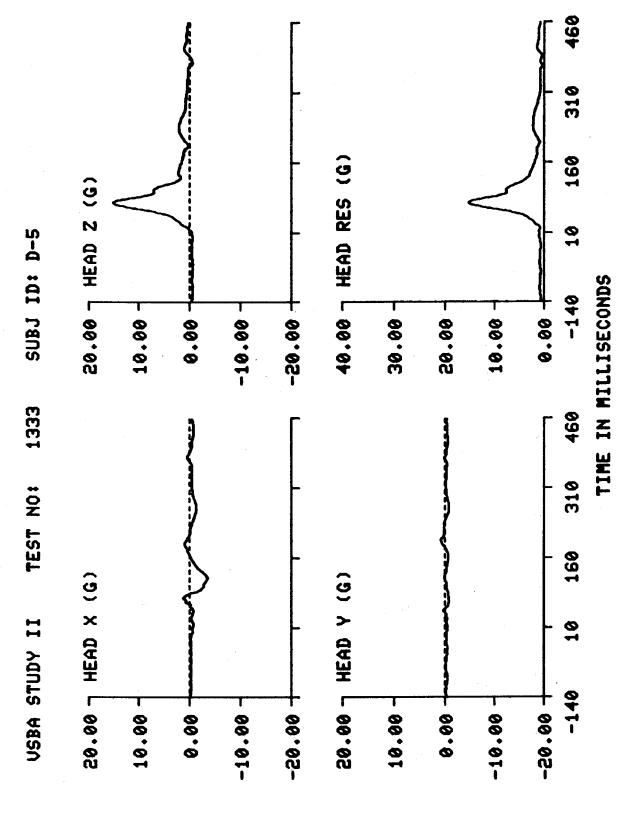


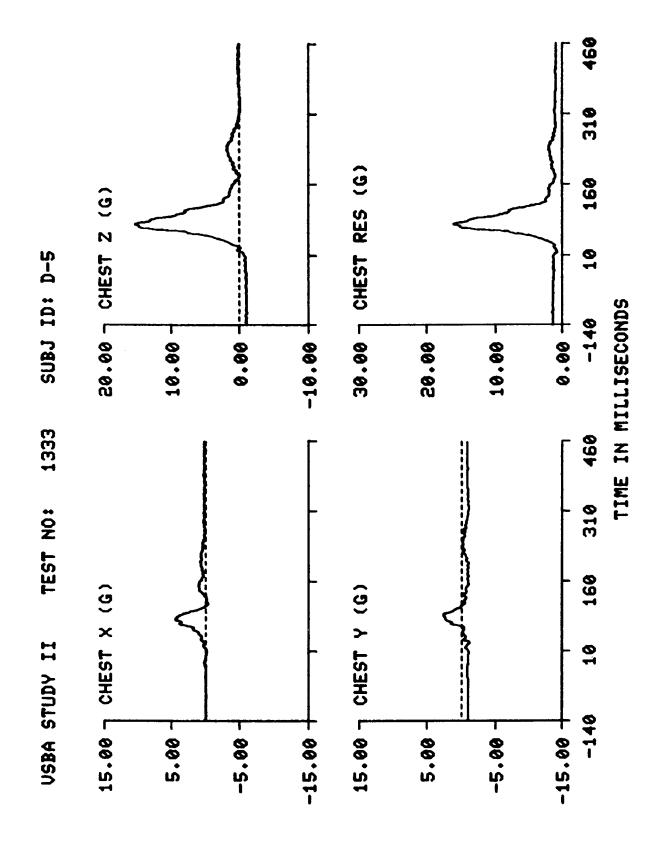
VSBA STUDY II TEST: 1333 SUBJ: 0-5 HT: 172.0 NOM G: 10.0 CELL: J

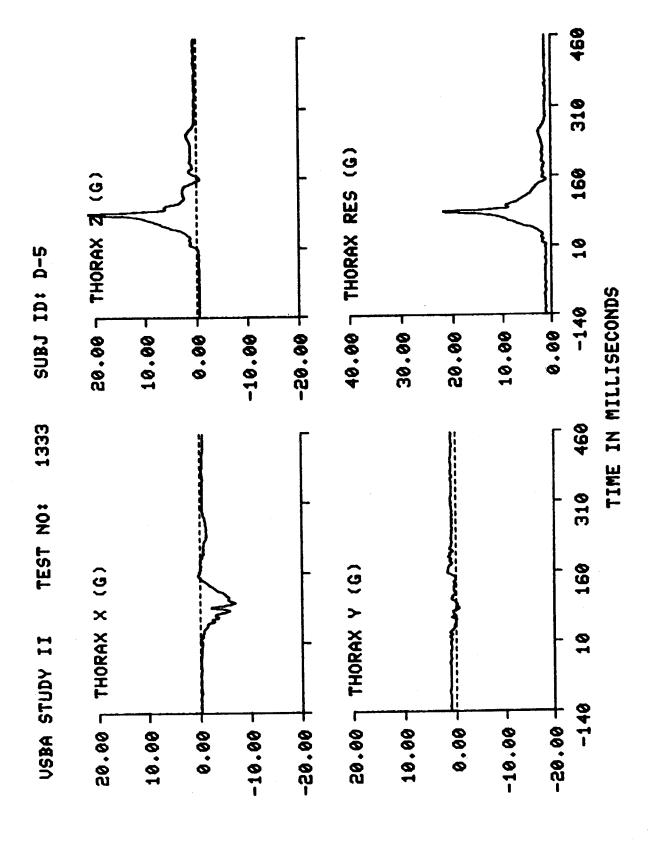
DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM	TIME OF MAXIMUM	
REFERENCE MARK 2.57 EXT PWR 107 EXT PWR		2.50 10.01	2.50 10.00	-147. 1. 0.	0. 1.
CARRIAGE ACCELERATION (G) X AXIS Y AXIS Z AXIS Z RXIS Z RXIS (SM)	-0.07 0.03 0.07 0.08	0.57 1.60 9.96 9.73	-0.48 -1.59 0.50 0.52	47. 58. 69. 69.	166. 54. 0.
SEAT ACCELERATION (G) X AXIS Y AXIS Y AXIS Z AXIS Z AXIS AXIS (SM) RY	-0.01 -0.07 0.14 0.14 9.49	1.79 0.79 11.16 10.28 36.75	-1.87 -0.75 0.33 0.41 -23.22	57. 80. 62. 71. 62.	53. 30. 0. 57.
CARRIAGE VELOCITY (F/S)	-26.83	-1.20	-27.73	357.	14.
CHEST ACCELERATION (G) X AXIS Y AXIS Z AXIS RESULTANT NORM RESULTANT 51 RY	0.10 -0.90 -0.86 1.25 0.13	4,47 2.61 15.33 16.10 1.65 29.50	-0.31 -1.24 -0.91 0.69 0.07	77. 86. 76. 76. 76. 80.	110. 27. 6. 17. 17.
HEAD ACCELERATION (G) X AXIS Y AXIS Z AXIS RESULTANT NORM RESULTANT SI RY	+0.25 -0.34 -0.47 0.63 0.07	1.24 0.81 15.20 15.26 15.27 24.92 281.04	-3.50 -0.87 -0.65 0.21 0.02 -204.43	72. 198. 74. 74. 74. 76.	116. 67. 1. 369. 969.
THORAX ACCELERATION (G) X AXIS Y AXIS Z AXIS RESULTANT NORM RESULTANT	-0.17 0.99 -0.31 1.05 0.11	0.44 1.62 21.51 21.81 2.24	-6.94 -0.65 -0.66 0.89	154. 158. 83. 83. 83.	96. 81. 158. 12.
SHOULDER LOADS (LB) X AXIS Y AXIS Z AXIS RESULTANT	61.29 2.76 -3.31 61.45	119.59 8.12 34.31 123.58	28.61 -1.02 -3.57 28.76	101. 97. 92. 101.	377. 34. 1. 382.
LAP LOADS (LB) LEFT X AXIS LEFT Y AXIS LEFT Z AXIS LEFT RESULTANT RIGHT X AXIS RIGHT Y AXIS RIGHT Y AXIS RIGHT Z AXIS RIGHT RESULTANT	45.05 13.73 41.27 62.62 26.31 11.79 31.99 43.06	76.78 17.03 45.29 90.27 68.06 25.49 47.81 83.93	15.20 4.70 -0.10 18.06 5.62 1.57 -3.23 7.81	96. 95. 1. 99. 92. 99. 100.	200. 212. 53. 200. 198. 201. 50.
SEAT LUADS (LB) LEFT LINK X AXIS RIGHT LINK X AXIS X AXIS CENTER LINK Y AXIS LEFT PAN Z AXIS RIGHT PAN Z AXIS CENTER PAN Z AXIS Z AXIS SUM Z AXIS MINUS TARE RESULTANT RESULTANT	0.74 -3.63 -2.88 -7.00 24.11 23.22 55.52 102.86 126.86 126.63	16.94 6.16 13.18 -4.42 764.17 596.03 1421.95 2639.87 2402.29 2645.72	-55.95 -11.89 -66.09 -170.27 30.91 24.71 64.21 122.92 140.45 123.49 140.94	178. 58. 177. 316. 83. 85. 72. 83. 77. 76. 77.	83. 85. 83. 71. 0. 338. 1. 1.

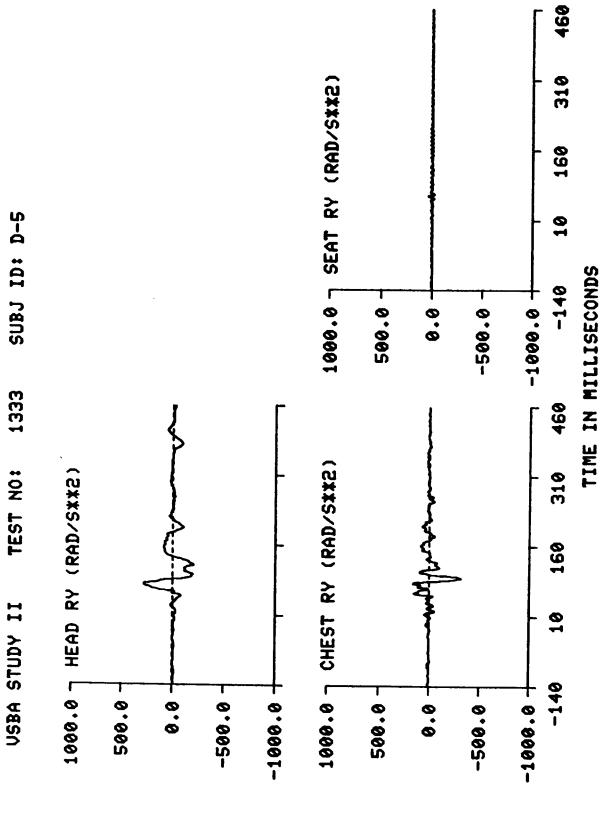


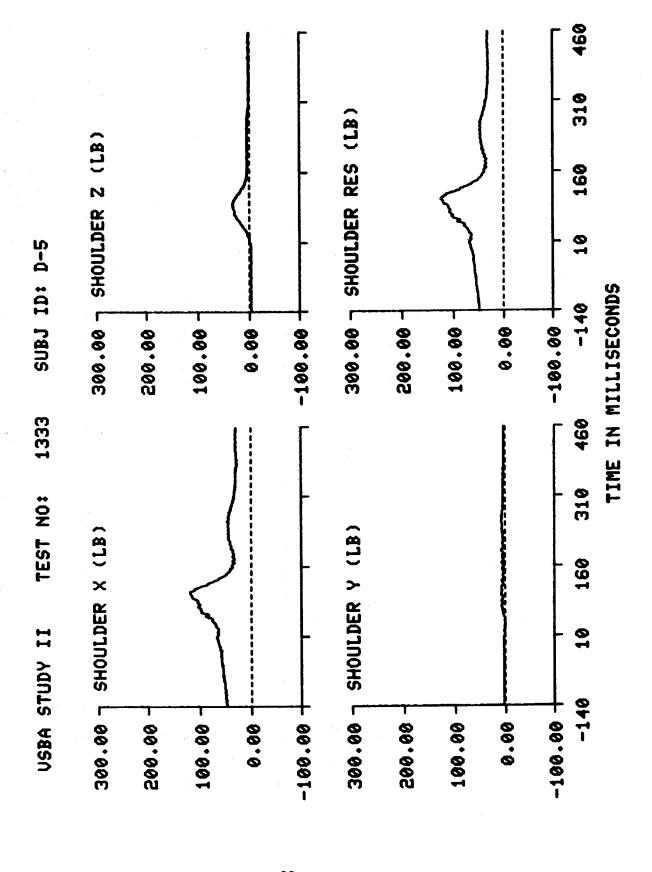


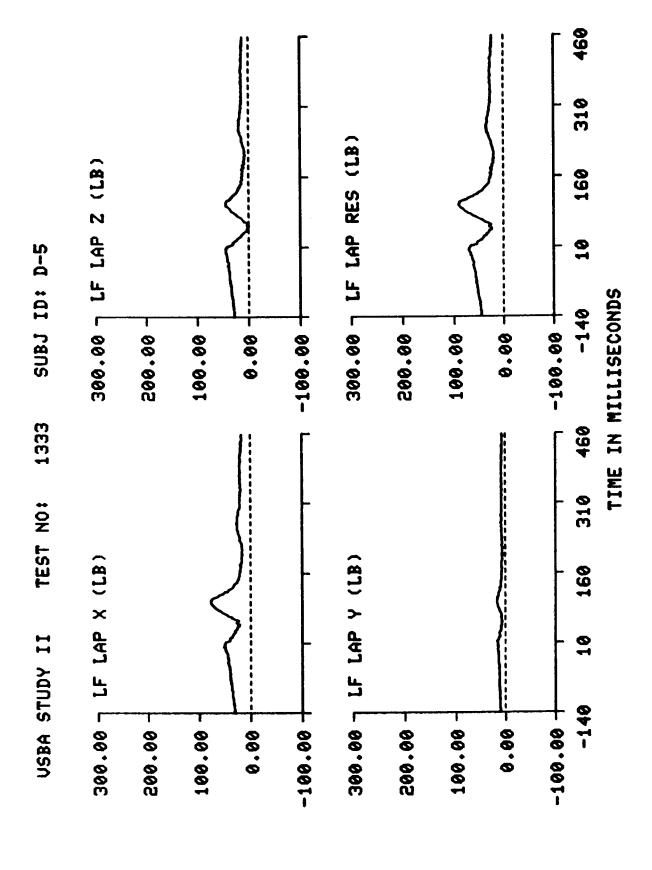


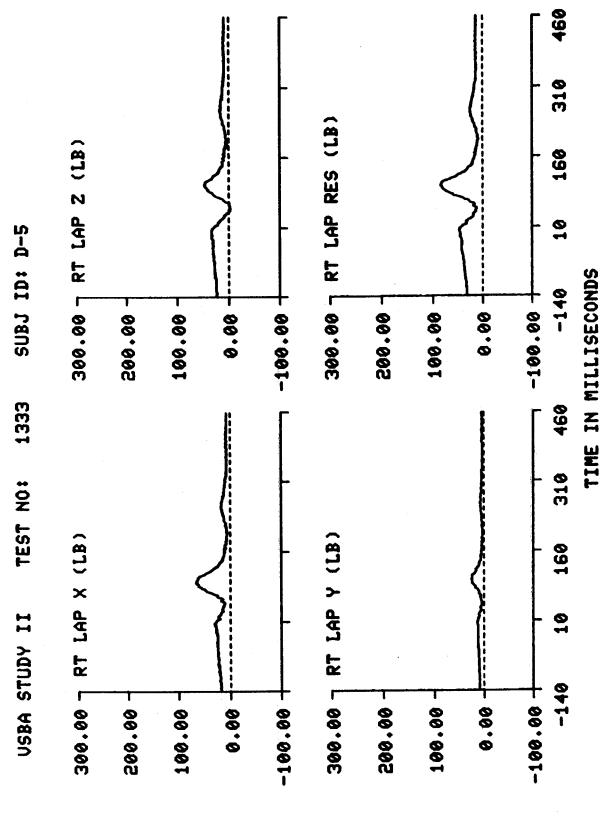


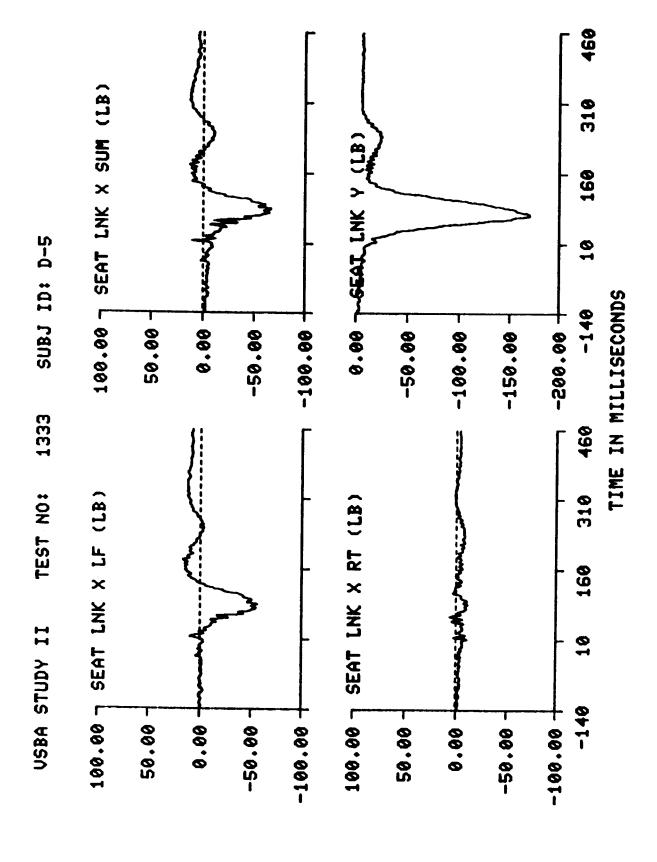


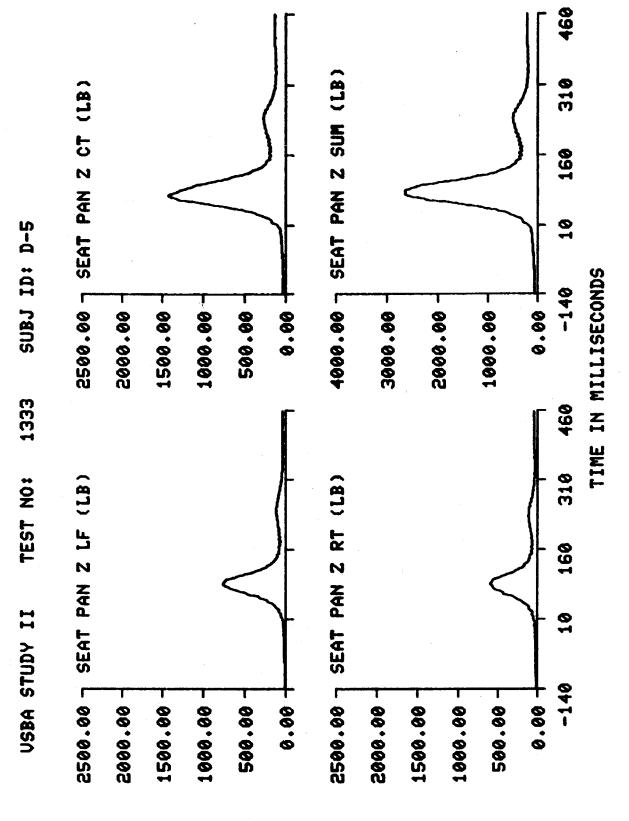


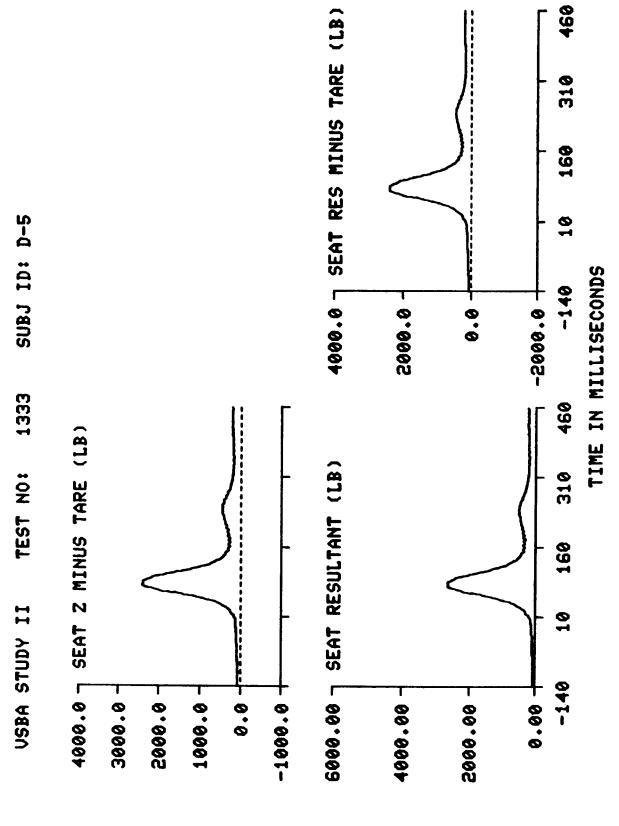












VSBR STUDY II TEST: 1346 SUBJ: 0-5 WT: 172.0 NOM G: 10.0 CELL: I

DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK 2.59 EXT PWR 10V EXT PWR		2.50 10.00	2.50 9.99	-148. 21. 2.	0. 0.
CARRIAGE ACCELERATION (G) X AXIS Y AXIS Y AXIS Z AXIS Z AXIS Z AXIS (SM)	0.00 -0.07 0.05 0.06	2.82	-1.77 0.49	12. 67.	16. 52. 0. 0.
SEAT ACCELERATION (G) X AXIS Y AXIS Z AXIS Z AXIS Z AXIS (SM) RY	-0.05 0.01 0.07 0.07 -1.41	1.52	-1.85 -1.04 0.37 0.37 -31.58	11. 50. 68. 69.	52. 70. 0. 0. 21.
CARRIAGE VELOCITY (F/S)	-27.01	-1.21	-27.58	358.	6.
CHEST ACCELERATION (G) X AXIS Y AXIS Z AXIS RESULTANT NORM RESULTANT SI RY	0.14 -0.68 -0.74 1.02 0.10	3.95 -0.08 17.07 17.20 1,77 35.81 358.68	-1.78 -0.80 0.59 0.06	95.	110. 57. 7. 14. 14.
HEAD ACCELERATION (G) X AXIS Y AXIS Z AXIS RESULTANT NORM RESULTANT SI RY	-0.28 -0.35 -0.49 0.67 0.07	0.81 0.22 16.94 16.98 1.78 28.47 580.38	-1.19 -0.59	73. 131. 74. 74. 74. 74.	118. 68. 10. 344. 344.
THORAX ACCELERATION (G) X AXIS Y AXIS Z AXIS RESULTANT NORM RESULTANT	-0.30 0.45 -0.29 0.62 0.06	0.30 5.79 20.57 20.86 2.14	-0.35	189. 85. 92. 92.	86. 22. 167. 171.
SHOULDER LOADS (LB) X AXIS Y AXIS Z AXIS RESULTANT	75.17 -0.33 -7.93 75.59	116.57 12.03 33.24 119.83	29.74 -4.10 -7.98 29.77	104. 69. 91. 104.	422. 147. 0. 450.
LAP LOADS (LB) LEFT X AXIS LEFT Y AXIS LEFT Z AXIS LEFT RESULTANT RIGHT X AXIS RIGHT Y AXIS RIGHT Z AXIS RIGHT Z AXIS RIGHT Z AXIS	41.21 10.84 61.15 39.53 16.05 47.35	12.30 45.13	-2.97 -13.08	9.	56. 51. 59. 48. 59. 56. 48.
SEAT LOADS (LB) LEFT LINK X AXIS RIGHT LINK X AXIS X AXIS CENTER LINK Y AXIS LEFT PAN Z AXIS RIGHT PAN Z AXIS CENTER PAN Z AXIS Z AXIS SUM Z AXIS MINUS TARE RESULTANT RESULTANT	-2.75 -3.25 -6.00 11.70 21.45 30.24 85.25 136.93 164.69 137.56 165.22	19.75 30.39 41.11 15.18 744.45 600.37 1639.63 2696.46 2445.13	-10.37 -8.02 -14.20 -19.64 25.95 93.22 144.30 153.10 153.57	82. 83. 82.	81. 133. 6. 69. 4. 353. 0. 0.

